SEP 26 1946 CLASSIFICATION CANCELLED

CONFIDENTIAL RESTRICTED

RM No. SL6H27

CLASSIFICATION CANCELLED

Authority J. W. Crowley 12/14/53 Dir. Aeron. Research NACA

By OES See NACA change # 2197

~~11G5.32~~

~~Vought F6U~~

~~CONFIDENTIAL FILE~~

Status:

Restriction/Classification Cancelled

NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

FREE-SPINNING TUNNEL TESTS OF A 1/20-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE

TED NO. NACA 2390

By

Walter J. Klinar

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

~~CLASSIFICATION CHANGED TO~~

RESTRICTED

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U.S.C. 50:31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Authority A. L. Sanford Date 12-6-50
Dir., Aeron. Research
NACA

By OES See form 420

TECHNICAL EDITING WAIVED

CONTAINS PROPRIETARY INFORMATION

W. F. Schmid

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

OCT 3 1946

CONFIDENTIAL RESTRICTED CLASSIFICATION CANCELLED

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

FREE-SPINNING TUNNEL TESTS OF A 1/20-SCALE MODEL

OF THE CHANCE VOUGHT XF6U-1 AIRPLANE

TED NO. NACA 2390

By Walter J. Klinar

SUMMARY

A spin investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/20-scale model of the Chance Vought XF6U-1 airplane. The effects of control settings and movements upon the erect and inverted spin and recovery characteristics of the model were determined for the normal-fighter condition. The investigation also included tests for the take-off fighter condition (wing-tip tanks plus fuel added) spin-recovery parachutes, and simulated pilot escape.

In general, for the normal-fighter condition, the model was extremely oscillatory in roll, pitch, and yaw. The angles of the fuselage varied from extremely flat to inverted attitudes, and the model rotated with the rudder in a series of short turns and glides. Recoveries by rudder reversal were rapid but the model would immediately go into a spin in the other direction. Recoveries by merely neutralizing the rudder were satisfactory when the elevator and ailerons were set to neutral, the ensuing flight path being a steep glide. Thus, it is recommended that all controls be neutralized for safe recovery from spins obtained on the airplane.

With the external wing-tip tanks installed, the spins were somewhat less oscillatory in roll but recovery could not be obtained unless full-down elevator was used in conjunction with the rudder. If a spin is entered inadvertently with the full-scale airplane with external wing-tip tanks installed and if recovery is not imminent after a recovery attempt is made, it is recommended that the tanks be jettinsoned and the controls neutralized.

Either an 8-foot tail or a 5-foot wing-tip spin-recovery parachute (drag coefficient 0.68 and 0.77, respectively) is recommended as an emergency spin-recovery device during demonstration spins.

If it should become necessary to jump from the spinning airplane, it appears that the outboard side is the optimum side from which the pilot should attempt to escape. Because of the violent oscillations that will probably be encountered, however, it may be advisable to install a positive ejection mechanism for the pilot to insure safe escape.

INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Navy Department, tests were performed in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a 1/20-scale model of the Chance-Vought XF6U-1 airplane. The airplane is a single-place, low-wing, jet fighter, and it is equipped with slotted flaps which are extended for the cruising, take-off, and landing condition.

The erect spin and recovery characteristics of the model were determined for the normal-fighter high-speed condition (flaps full up, landing gear retracted) and for the normal-fighter cruising condition (flaps extended 4°, landing gear retracted). Investigations were also conducted to determine the effects of installing external fuel tanks at the wing tips. Brief tests were made with the center of gravity moved forward and rearward of the normal center-of-gravity position. In addition, pilot-escape tests and tests to determine the effect of emergency spin-recovery tail and wing-tip parachutes were performed. Tests suggested by Chance-Vought with the model loaded to simulate a 2000-pound overload condition were not considered necessary, as it was felt that test results for this loading would be similar to the results obtained for the normal-fighter loading.

SYMBOLS

b	wing span, feet
S	wing area, square feet
$\bar{c}$	mean aerodynamic chord

$x/\bar{c}$ ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ ratio of distance between center of gravity and thrust line to mean aerodynamic chord (positive when center of gravity is below thrust line)

m mass of airplane, slugs

ρ air density, slug per cubic foot

μ relative density of airplane $\left(\frac{m}{\rho S b}\right)$

I_X, I_Y, I_Z moments of inertia about X-, Y-, and Z-body axes, respectively, slug-feet^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

α angle between thrust line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees

ϕ angle between span axis and horizontal, degrees

V full-scale true rate of descent, feet per second

Ω full-scale angular velocity about spin axis, revolutions per second

σ helix angle, angle between flight path and vertical, degrees (For this model, the average absolute value of the helix angle was approximately 3°.)

β approximate angle of sideslip at center of gravity, degrees (Sideslip is inward when the inner wing is down by an amount greater than the helix angle.)

APPARATUS AND METHODS

The 1/20-scale model of the Chance-Vought XF6U-1 airplane was furnished by the Bureau of Aeronautics, Navy Department, and was prepared for testing by Langley. The model was checked for dimensional accuracy and prepared for testing by the Langley Laboratory. A three-view drawing of the model as tested in the high-speed condition is shown in figure 1. The dimensional characteristics of the airplane are given in table I.

Photographs of the model for the normal-fighter high-speed and cruising conditions are shown in figures 2 and 3, respectively. Figure 4 is a photograph of the model with the wing-tip fuel tanks installed.

The model was ballasted with lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho = 0.001496$ slug per cubic foot). The external fuel tanks (957 pounds each, fully loaded, full scale) were independently ballasted in order that the proper change in mass distribution would be effected when the external fuel tanks were installed. A remote-control mechanism was installed in the model to actuate the controls or open the parachute for recovery tests, and also to release the pilot for the emergency escape tests. Sufficient moments were exerted on the control surfaces during recovery tests to reverse the controls fully and rapidly.

A 1/20-scale dummy model was built and ballasted at Langley to represent the pilot and parachute (200 pounds) at 15,000 feet.

Wind Tunnel and Testing Technique

The model tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is generally similar to the described in reference 1 for the Langley 15-foot free-spinning tunnel, except that the model-launching technique has been changed. With the controls set in the desired position, the model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, recovery is attempted by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. A photograph of the model during a spin is shown in figure 5.

The data presented were determined by methods described in reference 1 and have been converted to corresponding full-scale values. The turns for recovery are measured from the time the controls

are moved, or the parachute is opened, to the time the spin rotation ceases. Recovery in 2 turns or less has been adopted as the criterion for a satisfactory spin recovery for the model. For the spins which had a rate of descent in excess of that which can readily be attained in the tunnel, the rate of descent was recorded as greater than the velocity at the time the model hit the safety net, as >300. For these tests, the recovery was attempted before the model reached its final steeper attitude and while the model was still descending in the tunnel and such results are conservative. For recovery attempts in which the model struck the safety net while it was still in a spin, the recovery was recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery does not necessarily indicate an improvement over a >7-turn recovery.

Spin-tunnel tests are made to determine the spin and recovery characteristics of the model for the normal-spinning control configuration (elevator full up, ailerons neutral, and rudder full with the spin) and at various other aileron-elevator control combinations including zero and maximum deflections. Recovery is generally attempted by rapid full rudder reversal. Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal-control configuration for spinning. For these tests, the ailerons are set at one-third of the full deflection in the direction conducive to slower recoveries, and the elevator is generally set at two-thirds of its full-up deflection. For this model, tests were performed with the ailerons one-third with and one-third against the spin for the normal-fighter loading, as it was not obvious whether ailerons partially deflected with or against the spin would cause slower recoveries. For the take-off fighter loading, tests were performed with the ailerons one-third with the spin. Recovery is usually attempted by rapidly reversing the rudder from full with to two-thirds against the spin. The recovery characteristics of the model are considered satisfactory if recovery requires no more than $2\frac{1}{4}$ turns.

The testing technique for determining the optimum size of, and the towline length for, spin-recovery parachutes is described in detail in reference 2. For the tail parachute tests, the parachute pack and towline were attached to the model near the rear of the fuselage below the horizontal tail on the inboard side of the fuselage (right side of the fuselage in a right spin). As previously mentioned, the parachute was opened for the recovery attempts by actuating the remote-control mechanism. For the current spin-recovery parachute tests, the towline lengths between the model and the parachute was 35 feet when the parachute was attached at

the tail. Wing-tip parachutes were attached to the outer wing tip (left wing tip in a right spin). When the parachute was attached to the wing tip, the towline length was so adjusted that the parachute would just clear the fuselage. In every case, the folded parachute was placed on the fuselage or on the wing is such a position that it did not influence the steady spin before the parachute was opened. It is recommended that for full-scale wing-parachute installations, that the parachute be packed within the airplane structure. All parachutes should be provided with a positive means of ejection. For the current tests, the controls were not moved during recovery so recovery was due entirely to the effect of opening the parachute. Flat-silk parachutes having a drag coefficient of approximately 0.77 for the wing-tip parachutes and 0.68 for the tail parachutes (based upon the canopy area measured with the parachute spread out flat on a flat surface) were used for the spin-recovery parachute tests.

PRECISION

The model test results presented are believed to be the true values given by the model within the following limits:

α, degree	± 1
ϕ, degree	± 1
V, percent	± 5
Ω, percent	± 2
Turn for recovery	$\pm 1/4$ turn when obtained from motion-picture records $\pm 1/2$ turn when obtained by visual estimate

The preceding limits may have been exceeded for a large proportion of the spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and airplane spin results (references 1 and 3) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the model spun at a somewhat smaller angle of attack, at a somewhat higher rate of descent, and at from 5° to 10° more outward sideslip than did the airplane. The comparison made in reference 3 for 20 airplanes showed that 80 percent of the models predicted satisfactorily the number of turns required for recovery from the spin for the corresponding airplanes and that 10 percent overestimated and 10 percent underestimated the number of turns required. Little can be stated about

the precision of the pilot-escape tests as no comparable airplane data are available. It is felt, however, that if the dummy pilot is observed to clear all parts of the model by a large margin after being released, then the tests indicate that the pilot can safely escape.

Because it is impracticable to ballast the model exactly, and because of the inadvertent damage to the model during tests, the measured weight and mass distribution of the XF6U-1 model varied from the true scaled-down values within the following limits:

Weight, percent		1 low to 3 high
Center-of-gravity location, percent $\bar{c}$		1 forward to 2 rearward of normal
Moments of Inertia	I_X, percent	1 low to 4 high
	I_Y, percent	2 low to 6 high
	I_Z, percent	1 low to 6 high

The accuracy of measuring the weight and the mass distribution is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls were set with an accuracy of $\pm 1^{\circ}$.

TEST CONDITIONS

Tests were performed for the model conditions listed on table II. The mass characteristics and mass parameters possible on the airplane are indicated on table III. The mass parameters for the loadings possible on the XF6U-1 airplane, and for the loadings tested on the model, are also shown in figure 6. As discussed in reference 4, figure 6 can be used in predicting the relative effectiveness of the controls on the recovery characteristics of the model.

The tail-damping power factor was computed by the method described in reference 5.

The maximum control deflections used in the tests were:

Rudder, degrees	20 right, 20 left
Elevator, degrees	25 up, 20 down
Ailerons, degrees	17 up, 17 down

The intermediate control deflections used were:

Rudder, two-thirds deflected, degrees	13
Elevator, two-thirds up, degrees	17
Elevator, one-third down, degrees	7
Ailerons, one-third deflected, degrees	6 up, 6 down
Flaps, degrees (cruising)	4 down

Tests were performed with variations in center-of-gravity position in order to allow for the limits of accuracy of the computed full-scale and model values and also to allow for any rearrangement of loading that might lead to a spinning condition from which recovery might be slower than for the normal-fighter loading. The weight and mass distribution were held approximately constant when the center-of-gravity location was changed.

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented on charts 1 to 6 and on table V. The model data are presented in terms of the full-scale values for the airplane at a test altitude of 15,000 feet.

Preliminary tests of the model showed that recoveries from left and right spins differed very little. Results are arbitrarily presented in terms of equivalent right spins, that is, for the airplane turning to the pilot's right.

Normal-Fighter Loading

High-speed condition.- The test results obtained with the XF6U-1 model in the normal-fighter loading and high-speed condition (flaps and landing gear fully retracted) are presented in chart 1. The model loading condition is represented by point 1 on table III and figure 6. For the normal-control configuration for spinning (elevator full up, ailerons neutral, and rudder full with the spin), the model behaved as follows when the initial launching rotation was expended: the model became exceedingly oscillatory in pitch, yaw, and roll; the attitudes of the fuselage varied from extremely

flat to inverted angles, and the wings oscillated through a wide range; at times the model rolled the outboard wing down as it glided a short distance, then, as it began turning to the right again, the model would pick up the outboard wing and yaw the inboard wing downward. (See fig. 7.) The vertical airspeed during this motion varied from approximately 260 to 292 feet per second (full scale). Although recoveries by full rudder reversal were rapid, the model occasionally began turning in the other direction almost immediately after rudder reversal. (See fig. 8.) Neutralization of the rudder was not always sufficient to satisfactorily terminate the motion for this control configuration. For the control setting with both the ailerons and the elevator set to neutral, however, merely neutralizing the rudder did give satisfactory recoveries and the ensuing flight path after recovery was a steep glide. On the basis of these results, it is recommended that all controls be neutralized for safe recoveries from the spinning airplane.

When the ailerons were full against the spin and the elevator was full up, the motions of the model were as follows: When the initial spinning rotation to the right (imparted to the model on launching) was expended, the model became increasingly oscillatory in pitch, yaw, and roll until the outboard wing was yawed down approximately 90°; at this point the model rolled over on its back to the left (in the direction of the aileron setting) and then continued turning to the left in a series of erect and inverted attitudes that appeared to be a left roll. (See fig. 9.) During this motion the rudder remained fully deflected to the right (in the direction of the original spin rotation). Although the original spin rotation was thus terminated, it is possible that the airplane may encounter the same motions experienced by the model for this control setting, but neutralization of all controls should terminate the motion rapidly.

Setting the ailerons to full with the spin, elevator full up, resulted in a spin that was generally similar to the elevator-up, aileron-neutral spin. (See fig. 10.) Recovery by full rudder reversal from this control setting was rapid, but usually resulted in an inverted spin. (See fig. 11.)

Cruising condition.- Results obtained for tests with the model in the normal-fighter loading and cruising condition (flaps 4° deflected and landing gear retracted) are presented on chart 2. These results were generally similar to those obtained for the high-speed condition.

Center-of-Gravity Variation

Center of gravity, 5 percent mean aerodynamic chord forward of normal.- The results presented on chart 3 show the effects of moving the center of gravity 5 percent of the mean aerodynamic chord forward of the normal center-of-gravity position (obtained on the airplane by removal of the fuel in the rear tank and the oil). These results were generally similar to those obtained for the normal loading except that the oscillations encountered by the model for the normal-spin control configuration (ailerons neutral, elevator full up, and rudder full with the spin) were somewhat less violent with the center of gravity moved forward. In addition, when the ailerons were full against the spin and the elevator full up it was possible to obtain a flat spin from which recovery by rudder reversal was very slow.

Center of gravity, 20 percent mean aerodynamic chord rearward of normal.- Chart 4 shows the results obtained with the center of gravity moved 20 percent of the mean aerodynamic chord rearward of the normal position. (This center-of-gravity position can be obtained on the airplane by removal of the armament, the fuel in the front tank, and the navigation and miscellaneous equipment.) For this loading, the oscillations appeared to be accentuated and both aileron-against and aileron-neutral spins exhibited results similar to those previously obtained only for the aileron-against spins for the normal-fighter loading. The aileron-with spins were somewhat similar to the corresponding aileron-with spins obtained for the normal-fighter loading.

Effect of Installing External Wing-Tip Fuel Tanks

Take-off fighter loading.- The test results obtained with the fully-loaded wing-tip fuel tanks installed on the model to simulate the take-off fighter loading are presented on chart 5. This loading is represented by point 2 on table III and figure 6. As is shown on chart 5, the spins were somewhat oscillatory in pitch and yaw and recovery by rudder reversal alone was unsatisfactory. When the rudder reversal was accompanied by full and simultaneous reversal of the elevator, however, satisfactory recoveries were obtained. In order to obtain an indication of the sensitivity of the model to rudder and elevator movement during a recovery, recoveries were attempted by simultaneously reversing the rudder to only two-thirds against the spin and the elevator to one-third down. The ailerons were placed one-third with the spin (in the direction conducive to slow recoveries for this loading) the elevator was set full up, and the rudder was placed full with the spin for these tests.

An oscillatory spin was obtained for this control setting and recoveries were either satisfactory or unsatisfactory depending on whether the model was in the steep or flat phase of the oscillation, respectively. Thus, it appears that unsatisfactory recoveries may be obtained with the airplane in this loading unless special provisions are made on the airplane to insure full elevator and rudder reversal during the spin. Hence, if a spin is inadvertently encountered with the airplane in the take-off fighter loading, if recovery does not appear imminent after the normal manipulation of the controls (reversal of the rudder followed approximately $\frac{1}{2}$ turn later by reversal of the elevator) it is recommended that the following procedure be followed: jettison the wing-tip fuel tanks, pull the stick full back and laterally neutral, set the rudder with the spin, then briskly neutralize both rudder and elevator.

Asymmetric loading with one empty and one full external wing-tip fuel tank.- Chance-Vought requested that tests be made to determine the model spin characteristics with one full and one empty wing-tip tank installed. Chart 5 shows the results obtained with the model loaded to simulate the airplane with a fully loaded outer (left in a right spin) wing-tip fuel tank and an empty inner wing-tip fuel tank (point 3 on table III and fig. 6). When the rudder was fully reversed, the recoveries were generally unsatisfactory and were somewhat similar to those obtained for the take-off fighter loading. Unsatisfactory recoveries were also obtained by full simultaneous reversal of rudder and elevator.

With the model loaded asymmetrically in the other direction (full inner tank), the model wandered so badly that it could not be maintained in the tunnel long enough to obtain any test data.

Based on the results obtained with the wing-tip tanks installed on the model, jettisoning of the tanks as recommended for the take-off fighter condition is recommended for any loading condition with external fuel tanks installed.

2000-Pound Overload Condition

In order to simulate a condition of a general increase in over-all weight which is normally encountered in the development phase of new designs, it was suggested by Chance-Vought that a 2000-pound overload condition be simulated on the model, the radii of gyration and the center of gravity remaining the same as for the normal-fighter loading. These tests were not conducted because it appeared from the test results obtained with the normal loadings that such an overload condition would affect recoveries very slightly.

Inverted Spins

The results obtained for the inverted spin tests are presented on chart 6. The order used on the chart for presenting the data for inverted spins is defferent from that used for erect spins. For inverted spins, "controls crossed" (right rudder pedal forward and stick to the pilot's left when the airplane is spinning to the pilot's right) for the developed spin is plotted to the right of the chart and "stick back" is plotted at the bottom. When the controls are crossed in the developed spin, the ailerons aid the rolling motion; when controls are together, the ailerons oppose the rolling motion. The angle of wing tilt on the chart is given as up or down relative to the ground.

Nearly all of the inverted spins obtained were wandering and oscillatory, but recovery by full rudder reversal from these spins was generally satisfactory. As is indicated on the chart, the model would not spin inverted for several control settings, but would roll over into an erect spin. When the elevator and ailerons were set to neutral, merely neutralizing the rudder satisfactorily terminated the spin, and, accordingly, it is recommended all controls be neutralized for recovery from any inverted spin obtained on the airplane.

Spin-Recovery Parachutes

The results of tests performed with spin-recovery parachutes attached to either the outboard wing tip of the model or to the tail of the model are presented in table V. The model was in the normal loading for these tests.

With the spin-recovery parachute attached to the tail, the results indicated that satisfactory recovery would be obtained by opening an 8-foot (full-scale) diameter parachute with 35-foot towline. Satisfacotry recovery was also obtained when a 5-foot (full-scale) diameter parachute attached to the outboard wing tip of the model was opened. As previously mentioned, the towline length of parachute,attached to the wing tip was of such length that the over-all extended length of parachute, shroud lines, and towline just cleared the fuselage.

Pilot-Escape Tests

The results of the pilot-escape tests indicated that escape from the spinning airplane could be made from the outboard side (left side in a right spin) when the airplane is in the flat phase of the oscillatory spin, but when the airplane is in the steep phase of the oscillation, there is danger of the pilot hitting

the leading edge of the outboard wing. If, however, the pilot attempts to escape from the inboard side of the spinning airplane, the results of the model tests with the dummy pilot showed that he would hit the leading edge of the outboard wing when the airplane is in a flat attitude and that he would hit the stabilizer when the airplane is in a steep attitude. From these results, it appears that in an emergency, the pilot should jump from the outboard side during the flat phase of the oscillation so that he may get under the outboard wing immediately after he leaves the airplane. Because of the violent erratic oscillations encountered in the spin, it may be advisable to provide a positive ejection mechanism for the pilot to insure safe escape from the spinning airplane.

Control Forces

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to move the controls. For all tests, sufficient force was applied to the controls to move them fully and rapidly. Sufficient force must be applied to the airplane controls to move them in a similar manner in order for the model and airplane results to be comparable.

A hinge moment was applied to the rudder on the model equivalent to a 150-pound, full-scale, rudder pedal force, and model tests showed that this force would be sufficient to insure satisfactory recovery. This force is within the capabilities of a pilot. Because of the inertia, mass-balance effects, friction effects, and possible scale effects, these results are only a qualitative indication of the actual force that may be experienced.

Landing Condition

The landing condition (landing gear extended and flaps deflected 50°) was not tested on the model inasmuch as current Navy specifications require airplanes in the landing condition to demonstrate satisfactory recovery characteristics from only 1-turn spins. Experience indicates that a spinning airplane is still in the incipient phase of the spin at the end of 1 turn and recovery is usually readily obtained.

An analysis of results of full-scale and model tests to determine the effect of flaps and landing gear indicates that the XF6U-1 airplane will recover satisfactorily from a 1-turn incipient spin in the landing condition but that recoveries from fully developed spins in the landing condition may be unsatisfactory. It is recommended therefore that the flaps be neutralized and recovery

attempted immediately upon inadvertently entering a spin in the landing condition in order to insure that transition from the incipient to the fully developed spin does not take place.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the results of spin tests of a 1/20-scale model of the Chance-Vought XF6U-1 airplane, the following conclusions and recommendations regarding the spin and recovery characteristics of the airplane at 15,000 feet are made:

1. For the normal fighter loading, with the airplane in either the cruising or high-speed configuration, the airplane will be violently oscillatory in pitch, yaw, and roll; reversing the rudder will effect rapid recoveries but will probably cause the airplane to begin spinning in the other direction; neutralization of all controls is recommended for recovery because this procedure will terminate the spin, and the ensuing flight path after recovery will be a steep glide.

2. Moving the center of gravity forward will tend to cause the airplane to spin somewhat less violently whereas moving the center of gravity rearward will tend to accentuate the oscillations in the spin.

3. For the take-off fighter loading, full elevator reversal will probably be required in conjunction with rudder reversal to insure satisfactory recovery. If recovery does not appear imminent after a recovery attempt is made, the tanks should be jettisoned.

4. Satisfactory recoveries from inverted spins will be obtained by neutralizing all controls.

5. A 5-foot wing parachute or an 8-foot tail parachute (drag coefficient 0.77 and 0.68, respectively) will be effective for emergency recoveries from demonstration spins.

6. If it is necessary for the pilot to abandon the spinning airplane, he should attempt escape from the outboard side during the flat phase of the oscillation. Because of the erratic oscillatory motion indicated for the airplane during the spin, it may be advisable to provide positive ejection mechanism for the pilot to insure that he clears the airplane.

7. The rudder pedal force required to effect a recovery will probably be within the capabilities of the pilot.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

Walter J. Klinar

Walter J. Klinar
Aeronautical Engineer

Approved: Hartley A. Soule'

Hartley A. Soule'
Chief of Stability Research Division

CJB

REFERENCES

1. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. No. 557, 1936.

2. Seidman, Oscar, and Kamm, Robert W.: Antispin-Tail-Parachute Installations. NACA RB, Feb. 1943.

3. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wind-Tunnel Results with Corresponding Full-Scale Spin Results. NACA MR, Dec. 7, 1938.

4. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery from a Spin. NACA ARR, Aug. 1942.

5. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN No. 1045, 1946.

SUPPLEMENTARY REFERENCES

1. Chance-Vought Aircraft Drawing Nos.:
   CVS - 11272 Side View, 1/20 (0.05)- Size XF6U-1 W.T. Model, Free-Spinning Tunnel

   CVS - 11273 Plan View, 1/20 (0.05) - Size XF6U-1 W.T. Model, Free-Spinning Tunnel

   CVS - 11275 Front View, 1/20 (0.05) - Size XF6U-1 W.T. Model, Free-Spinning Tunnel

   CV4 500,000 General Arrangement, Model XF6U-1

2. Olison, T. J.: Weight and Balance Statement and Computation of Moments of Inertia. United Aircraft Corp., June 1945. Amended by NACA Let. to Bureau of Aeronautics, April 30, 1946.

TABLE I

DIMENSIONAL CHARACTERISTICS OF THE XF6U-1 AIRPLANE

Length, over all, ft	32.83
Normal weight, lb	9025.2
Normal center-of-gravity location, percent $\bar{c}$	31.03
Wing:	
Span, ft	32.83
Area, sq ft	203.5
Section, root	NACA 65(215)-114 (a = 1)
Section, tip	NACA 65_1-212 (a = 0.6)
Root-chord incidence, deg	2.0
Tip-chord incidence, deg	-1.0
Aspect ratio	5.3
Sweepback of leading edge, deg	4.34
Dihedral of wing, deg	4
Mean aerodynamic chord, in.	77.5
Leading edge $\bar{c}$ aft leading-edge root chord, in.	6.75
Flaps:	
Total area, sq ft	33.60
Mean chord, percent of $\bar{c}$	33.1
Span, percent of b/2	50.0
Ailerons:	
Total area, sq ft	20.40
Total area aft of hinge line, sq ft	14.20
Mean chord, percent of $\bar{c}$	26.5
Span, percent of b/2	36.1
Horizontal tail surfaces:	
Total area, sq ft	45.8
Span, ft	14.3
Elevator area, sq ft	15.0
Distance from normal c.g. to elevator hinge line, ft	16.19
Vertical tail surfaces:	
Total area, sq ft	26.60
Total rudder area, sq ft	9.4
Distance from normal c.g. to rudder hinge line, ft	16.51
Tail-damping power factor	803×10^{-6}

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II.- CONDITIONS TESTED ON THE 1/20-SCALE MODEL OF

THE CHANCE VOUGHT XF6U-1 AIRPLANE

[Cockpit closed; landing gear retracted; spins to the pilot's right]

Type of spin	Loading	Flap position	Method employed in recovery attempt	Data presented
Erect	Normal fighter	Retracted	Rudder reversal and rudder neutralization	Chart 1
Erect	Normal fighter	4° deflected (cruising setting)	Rudder reversal	Chart 2
Erect	Center of gravity 5 percent $\bar{c}$ forward	Retracted	Rudder reversal	Chart 3
Erect	Center of gravity 20 percent $\bar{c}$ rearward	Retracted	Rudder reversal	Chart 4
Erect	Take-off fighter (full wing-tip fuel tanks installed)	Retracted	Rudder reversal and simultaneous rudder and elevator reversal	Chart 5
Erect	Normal fighter with full outer and empty inner wing-tip fuel tanks	Retracted	Rudder reversal	Chart 5
Inverted	Normal fighter	Retracted	Rudder reversal and rudder neutralization	Chart 6
Erect	Normal fighter	Retracted	Tail and wing-tip parachutes	Table V

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE III.- LOADINGS OF THE XF6U-1 AIRPLANE

No.	Loading	Weight (lb)	Center-of-gravity location		Moments of Inertia			Mass Parameters			μ sea level	μ 15,000 ft
			$x/\bar{c}$	$z/\bar{c}$	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$		
1	Normal fighter	9,025.2	0.310	-0.076	3,975	11,766	14,587	-258×10^{-4}	-93×10^{-4}	351×10^{-4}	17.63	28.00
2	Take-off fighter (normal-fighter loading plus full wing-tip fuel tanks installed)	10,939.2	.327	-.0658	21,022	12,142	31,942	242	-540	298	21.38	33.95
3	Normal fighter with one full wing-tip tank and one empty wing-tip tank	10,099.2	.321	-.0697	13,550	11,992	24,323	46	-365	319	19.73	31.38
4	Center of gravity, 5 percent $\bar{c}$ forward of normal	8,078.7	.259	-.058	3,924	11,325	14,147	-274	-105	379	15.79	25.12
5	Center of gravity, 22 percent $\bar{c}$ rearward of normal	6,753.5	.526	-.066	3,855	9,577	12,436	-254	-126	380	13.20	20.99
6	Fuel and armament removed from normal fighter	5,848.8	.471	-.040	3,704	9,478	12,463	-296	-152	448	11.43	18.18
7	Fuel removed from normal fighter	6,770.7	.315	-.031	3,770	10,950	13,911	-317	-131	448	13.23	21.05
8	Armament removed from normal fighter	8,103.3	.421	-.086	3,925	10,383	13,214	-238	-104	342	15.84	25.20

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE IV.- WEIGHT, CENTER-OF-GRAVITY LOCATION, AND INERTIA MASS PARAMETERS OF THE XF6U-1 AIRPLANE AND OF THE 1/20-SCALE MODEL IN THE NORMAL LOADING

[Moments of inertia about center of gravity, model values converted to corresponding full-scale values]

	Airplane values	Minimum model values during test	Maximum model values during test
Mass (slugs)	280.3	277.5	287.9
I_X (slug-ft^2)	3,975	3,946	4,133
I_Y (slug-ft^2)	11,766	11,685	12,266
I_Z (slug-ft^2)	14,587	14,543	15,265
$\frac{I_X - I_Y}{mb^2} \times 10^4$	-258	-255	-262
$\frac{I_Y - I_Z}{mb^2} \times 10^4$	-93	-89	-97
$\frac{I_Z - I_X}{mb^2} \times 10^4$	351	348	359
$x/\bar{c}$	0.31	0.30	0.33
$z/\bar{c}$	-0.076	-0.064	-0.076
μ sea level	17.63	17.47	18.12
μ 15,000 ft	28.00	27.78	28.82

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE V.- SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH

THE 1/20-SCALE MODEL OF THE XF6U-1 AIRPLANE

[Normal loading; recovery attempted by opening the parachute with the rudder full with the spin; right erect spins]

Parachute diameter (ft)	[a]Towline length (ft)	Turns for recovery from elevator-up, aileron-neutral spins V = 269 to 292 fps
Tail parachutes (C_D = 0.68)		
10.0	35.0	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{2}$
8.8	35.0	$\frac{1}{4}$, $\frac{1}{2}$, 1, $1\frac{3}{4}$
8.0	35.0	$\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$, 2
7.0	35.0	$>1\frac{1}{2}$, >2, $>2\frac{1}{2}$
Wing-tip parachutes (C_D = 0.77)		
8.0		1
7.0		$\frac{1}{2}$, 1
6.2		$\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$
5.0		$\frac{1}{2}$, $\frac{1}{2}$, $\frac{3}{4}$
3.3		$1\frac{1}{2}$, 2, $>1\frac{1}{2}$, $>2\frac{1}{2}$

[a]The length of the towline for the wing-tip parachutes was such that the over-all extended length of parachute, shroud lines, and towline was approximately equal to the distance from the wing tip to the fuselage.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE IN THE HIGH-SPEED CONDITION

[Normal fighter loading (point 1 on table III and figure 6); recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from and steady spin data presented for, rudder-full-with spins); right erect spins.]

Control settings	Ail. against	Ail. neutral / Ail. $\frac{1}{3}$	Ail. with
Elev. up	See figure 9. Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90 degrees, and then model goes into a left roll.	See figure 7. Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from extremely flat to inverted angles. At times model glides short distances as it rolls outboard wing down, then turns right again. Vertical velocity: 260 to 292. Full rudder reversal: $\frac{1}{4}$ Goes into a spin in other direction, see figure 8. 1 Glides out. Recovery attempted before model is in final attitude. Neutralizing rudder: $1\frac{1}{2}$, $>2\frac{1}{4}$ When model recovered, it came out in a glide.	See figure 10. Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from extremely flat to inverted angles. At times, model glides short distances and then turns to the right again. Vertical velocity: 139. $\frac{1}{4}$ Goes into an inverted spin, see figure 11. $\frac{1}{4}$ Recovers in a glide
Elev. $\frac{2}{3}$ up	Ail. $\frac{1}{3}$ against: Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90 degrees, and then model goes into a left roll.	Ail. $\frac{1}{3}$ with: Oscillates widely in pitch, yaw, and roll. Glides for short distances as it pitches nose upward, then pitches nose downward again as it turns to the right. Vertical velocity: 293. Rudder reversed to two-thirds against the spin: $\frac{1}{2}$ Goes into a spin in the other direction $\frac{1}{4}$ Glides out $\frac{1}{4}$ Goes into an inverted spin.	
Elev. neutral	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90 degrees, and then model goes into a left roll.	Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from extremely flat to inverted angles. At times model glides short distances as it rolls outboard wing down, then turns right again. Vertical velocity: 253. Full rudder reversal: $\frac{1}{2}$, $\frac{3}{4}$ Goes into a spin in the other direction Neutralizing rudder: $\frac{1}{4}$, $1\frac{1}{2}$ Glides out.	Steep, tight spin with a whip. Inboard wing is down approximately 30 degrees during the spin. Vertical velocity: 300. 1 Goes into an inverted spin. (Visual estimate) $1\frac{1}{4}$ Goes into an inverted spin
Elev. down	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90 degrees, and then model goes into a left roll.	Model becomes increasingly oscillatory in pitch, yaw, and roll, and eventually makes a left roll. After model makes approximately one complete roll to the left, it appears to go into a wide radius inverted spin. Vertical velocity: 260 to 300	Steep, tight spin with a whip. Oscillates in yaw. Vertical velocity: 312. $\frac{3}{4}$ Goes into an inverted spin. $>1\frac{3}{4}$ Recovery attempted before model is in final steep attitude

Key to control settings

Ail. against - Elev. up	Ail. neutral - Elev. up	Ail. with - Elev. up
Ail. $\frac{1}{3}$ against - Elev. $\frac{2}{3}$ up		Ail. $\frac{1}{3}$ with - Elev. $\frac{2}{3}$ up
Ail. against - Elev. neutral	Ail. neutral - Elev. neutral	Ail. with - Elev. neutral
Ail. against - Elev. down	Ail. neutral - Elev. down	Ail. with - Elev. down

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Legend

Description of steady spin (rudder with the spin). Approximate full-scale velocities given in ft/sec.
Number of turns required for recovery and description of flight path after recovery. All recoveries are by full rudder reversal unless indicated otherwise.

CONFIDENTIAL

CONFIDENTIAL

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE IN THE CRUISING CONDITION

[Normal fighter loading (point 1 on table III and figure 6); flaps extended 4°; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

Control setting	Description of steady spin (rudder with the spin)	Turns for recovery and flight path after recovery
Ail. against - Elev. up	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	
Ail. neutral - Elev. up	Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from very flat to steep angles. At times model glides short distances as it rolls outboard wing down, then turns right again. Vertical velocity: 235 to 292.	$\frac{3}{4}$, 1 Goes into a glide.
Ail. with - Elev. up	Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from very flat to inverted angles. Rolls left wing down as it goes into short glides, and then turns right again. Vertical velocity: 326.	$\frac{3}{4}$ Goes into a spin in the other direction. 1 Goes into an inverted spin.
Ail. $\frac{1}{3}$ against - Elev. $\frac{2}{3}$ up	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	
Ail. $\frac{1}{3}$ with - Elev. $\frac{2}{3}$ up	Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from flat to inverted angles. Glides short distances as it rolls left wing down, then turns right again. V: 292	Rudder reversed to two-thirds against the spin: $\frac{1}{4}$ Goes into a glide. $\frac{3}{4}$ Goes into a spin in other direction.
Ail. against - Elev. neutral		
Ail. neutral - Elev. neutral	Oscillates widely in pitch, yaw, and roll. Attitudes of fuselage vary from very flat to inverted angles. Rolls left wing down as it goes into short glides and then turns right again. Vertical velocity: 254	$\frac{1}{4}$ Goes into a spin in other direction. $\frac{3}{4}$ Goes into a dive.
Ail. with - Elev. neutral		
Ail. against - Elev. down		
Ail. neutral - Elev. down	Model becomes increasingly oscillatory in pitch, yaw, and roll, and eventually makes a roll to the left. After model makes approximately two complete rolls to the left, it appears to go into an inverted glide. Vertical velocity: 241.	
Ail. with - Elev. down		

Key to control settings

Ail. against - Elev. up	Ail. neutral - Elev. up	Ail. with - Elev. up
Ail. $\frac{1}{3}$ against - Elev. $\frac{2}{3}$ up		Ail. $\frac{1}{3}$ with - Elev. $\frac{2}{3}$ up
Ail. against - Elev. neutral	Ail. neutral - Elev. neutral	Ail. with - Elev. neutral
Ail. against - Elev. down	Ail. neutral - Elev. down	Ail. with - Elev. down

Legend

Description of steady spin (rudder with the spin). Approximate full-scale velocities given in feet per second.
Number of turns required for recovery and description of flight path after recovery. All recoveries are by full rudder reversal unless indicated otherwise.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

CONFIDENTIAL

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE WITH CENTER OF GRAVITY MOVED FIVE PERCENT MEAN AERODYNAMIC CHORD FORWARD

[Center of gravity five percent mean aerodynamic chord forward of normal (point 4 on table III and figure 6); flaps fully retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

Ail. against - Elev. up

51 to 66	8U to 2D	Model oscillates in pitch. In addition to the spin data presented the model also went into a left roll for this control setting.
198		

8 Goes into a dive (visual estimate).

Ail. neutral - Elev. up

38 to 69	24U to 14D	Oscillates widely in pitch, yaw, and roll.
241		

1 Goes into a dive.

$1\frac{1}{4}$ Goes into a spin in other direction.

Ail. with - Elev. up

Oscillates widely in pitch, yaw, and roll. Model glides short distances as it rolls left wing down, and then starts turning right again. Vertical velocity: 306.

$\frac{1}{4}$, $\frac{1}{2}$ Goes into a spin in the other direction.

Ail. $\frac{1}{3}$ against - Elev. $\frac{2}{3}$ up

36 to 69	31U to 24D	Oscillates widely in pitch, yaw, and roll.
245	0.35	

Rudder reversed to two-thirds against the spin

1 Goes into a glide.

$1\frac{1}{2}$ Goes into a spin in other direction.

Ail. $\frac{1}{3}$ with - Elev. $\frac{2}{3}$ up

Oscillates widely in pitch, yaw, and roll. Model glides short distances as it rolls left wing down, and then starts turning right again. Vertical velocity: 306.

Rudder reversed to two-thirds against the spin

$\frac{1}{4}$ Goes into spin in other direction (visual estimate).

Ail. against - Elev. neutral

Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90° and then model goes into a left roll.

Ail. neutral - Elev. neutral

Oscillates widely in pitch, yaw, and roll. Model goes into short glides and then starts turning to the right again. Vertical velocity: 248.

1 Goes into a spin in the other direction.

1 Goes into a dive.

Ail. with - Elev. neutral

(blank)

Ail. against - Elev. down

(blank)

Ail. neutral - Elev. down

Oscillates widely in pitch, yaw, and roll. At times model skids outward on the outboard wing and then starts turning to the right again. Vertical velocity: 241.

$\frac{1}{2}$, 1 Goes into a dive.

Ail. with - Elev. down

(blank)

Key to control settings

Ail. against - Elev. up	Ail. neutral - Elev. up	Ail. with - Elev. up
Ail. $\frac{1}{3}$ against - Elev. $\frac{2}{3}$ up		Ail. $\frac{1}{3}$ with - Elev. $\frac{2}{3}$ up
Ail. against - Elev. neutral	Ail. neutral - Elev. neutral	Ail. with - Elev. neutral
Ail. against - Elev. down	Ail. neutral - Elev. down	Ail. with - Elev. down

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

Legend

α°	ϕ°	Description of steady spin (rudder with the spin). Approximate full-scale velocities given in feet per second.
V ft/sec	$\frac{\Omega}{\text{rps}}$	
Number of turns required for recovery and description of flight path after recovery. All recoveries by full rudder reversal unless indicated otherwise.		

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

CONFIDENTIAL

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE WITH CENTER OF GRAVITY MOVED 20 PERCENT MEAN AERODYNAMIC CHORD REARWARD

[Center of gravity 20 percent mean aerodynamic chord rearward of normal (point 5 on table III and figure 6); flaps fully retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	Oscillates widely in pitch as model goes into a wide radius spin; wings oscillate up and down rapidly. Vertical velocity: 248. $\frac{1}{4}$, $\frac{1}{2}$ Goes into a right roll.
Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	
	Model becomes increasingly oscillatory in pitch, yaw, and roll till outboard wing is yawed down approximately 90°, and then model goes into a left roll.	Series of quick turns and dives. At times model rolls completely over to the left, and then turns right again. Vertical velocity: 241. $\frac{1}{2}$, $\frac{1}{2}$ Goes into an inverted spin.

Elevator full up (Stick back)

Ailerons full against (Stick left)

Ailerons full with (Stick right)

Elevator full down (Stick forward)

Legend

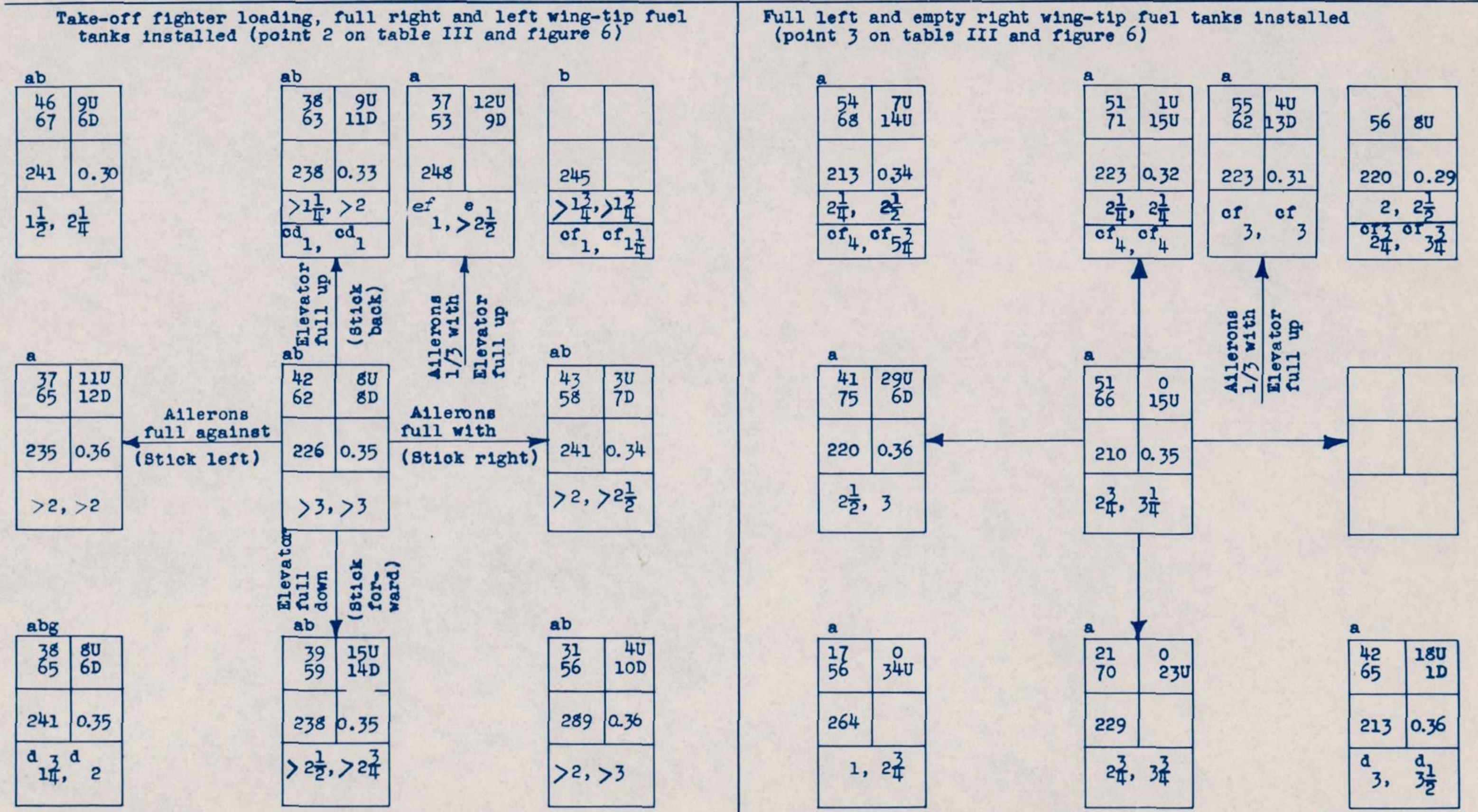
Description of steady spin (rudder with the spin). Approximate full-scale velocities given in ft/sec.
Number of turns required for recovery and description of flight path after recovery.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE WITH WING-TIP FUEL TANKS INSTALLED

[Loading as indicated; flaps fully retracted; recovery attempted by full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



[a]Oscillatory spin, range or average value given.
[b]Wandering spin.
[c]Recovery attempted by simultaneous full reversal of rudder and elevator.
[d]Goes into inverted flight on recovery.
[e]Recovery attempted by simultaneous reversal of rudder to 2/3 against the spin and elevator to 1/3 down.
[f]Goes into an inverted spin on recovery.
[g]In addition to the spin presented, model also stopped spinning without reversing the rudder.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 6.- INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE VOUGHT XF6U-1 AIRPLANE

[Normal fighter loading (point 1 on table III and figure 6); flaps fully retracted; recovery attempted by rapid full rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); model rotation to the pilot's right (right pedal forward during steady spin, left rudder pedal moved forward for recovery)]

Stick full right, stick forward	Stick forward	Stick full left, stick forward
Model does not remain in an inverted spin, but rolls over into an erect spin (rudder with the spin).	Model oscillates in pitch and yaw, and wanders badly. There is a slight whip to the turning motion. Vertical velocity: 286.	Oscillates widely in pitch and yaw and wanders. Goes into short inverted glides as it rolls outboard wind down, then turns with the rudder. Attitudes of fuselage vary from moderately steep inverted to steep erect angles. Vertical velocity: 306.
	$\frac{1}{2}$, $\frac{1}{2}$ Glides out inverted	$\frac{1}{4}$ Goes into an erect spin.

Stick forward

Stick full right (Controls together)	Stick neutral	Stick full left (Controls crossed)
α: 31° to 47°; ϕ: 11°U to 1°D; V: 296; Ω : 0.40 Oscillates slightly in pitch.	Model oscillates in pitch and yaw, and wanders badly. There is a whip to the turning motion. Vertical velocity: 303.	Oscillates widely in pitch and yaw and wanders. Turning motion has a whip to it. Attitudes of fuselage vary from moderately steep inverted to steep erect angles. Vertical velocity: 306.
$\frac{1}{4}$, $\frac{1}{4}$ Goes into a spin in the other direction.	Rudder reversal 1 Goes into a dive. $\frac{1}{2}$ Goes into spin in other direction. Neutralizing rudder $\frac{1}{4}$, $\frac{1}{2}$ Goes into erect glide.	$\frac{1}{2}$ Goes into an erect spin.

Stick back

Stick full right, stick back	Stick back	Stick full left, stick back
Model does not remain in an inverted spin, but rolls over into an erect spin (rudder with the spin).	Model does not remain in an inverted spin, but rolls over into an erect spin (rudder with the spin).	Steep spin with a whip to the turning motion. Wings oscillate through wide angles and model wanders. Vertical velocity: 316.
		1, $1\frac{1}{2}$ Goes into an erect spin.

Legend

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

Description of steady spin (rudder with the spin) V and Ω are approximate full-scale values in ft/sec and rev/sec, respectively.
Number of turns for recovery and description of flight path after recovery. All recoveries by full rudder reversal unless indicated otherwise.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

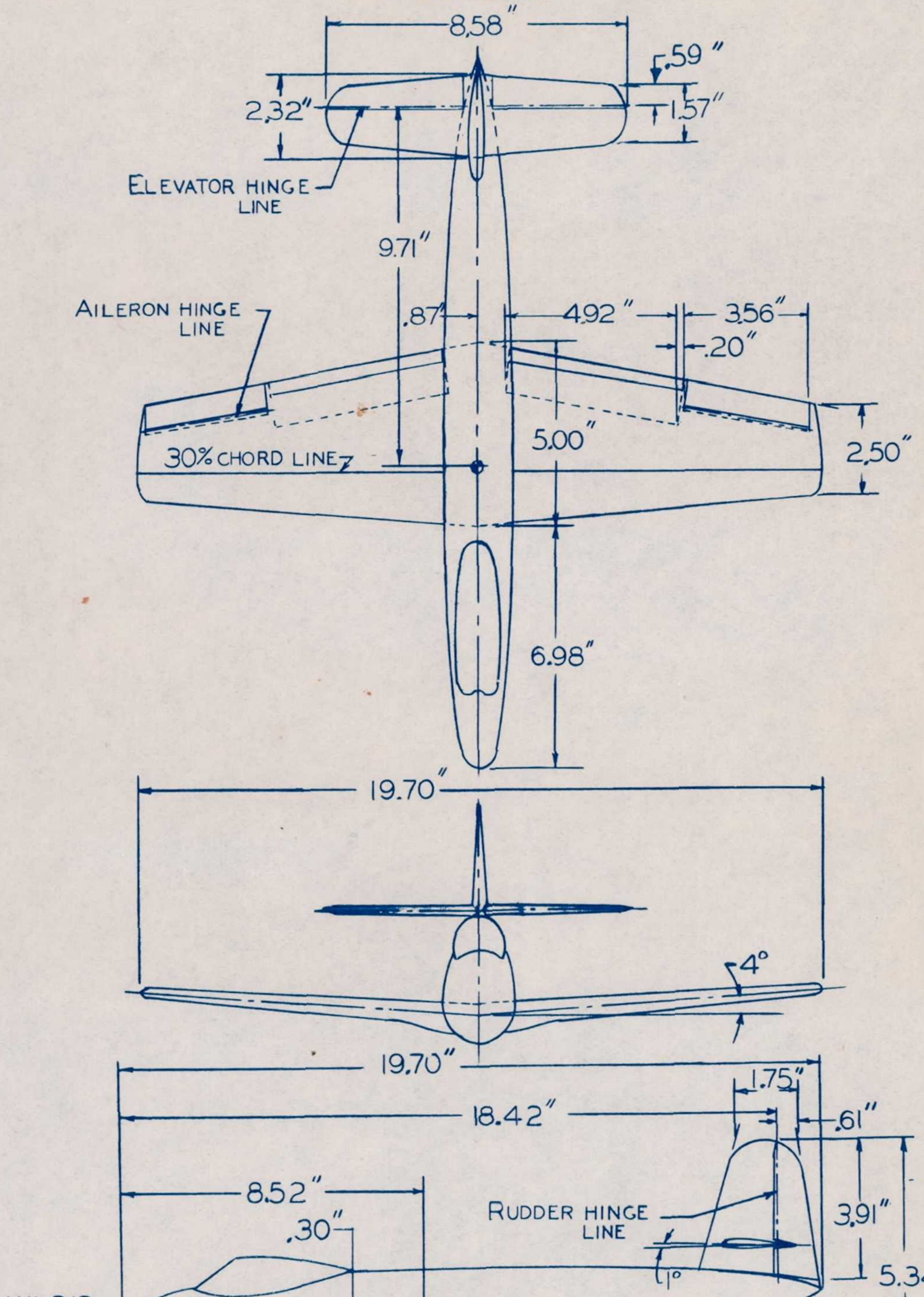


FIGURE 1. - DRAWING OF THE $\frac{1}{20}$-SCALE MODEL OF THE CHANCE-VOUGHT XF6U-1 AIRPLANE TESTED IN THE FREE-SPINNING TUNNEL. CENTER OF GRAVITY INDICATED FOR NORMAL FIGHTER LOADING.

CONFIDENTIAL

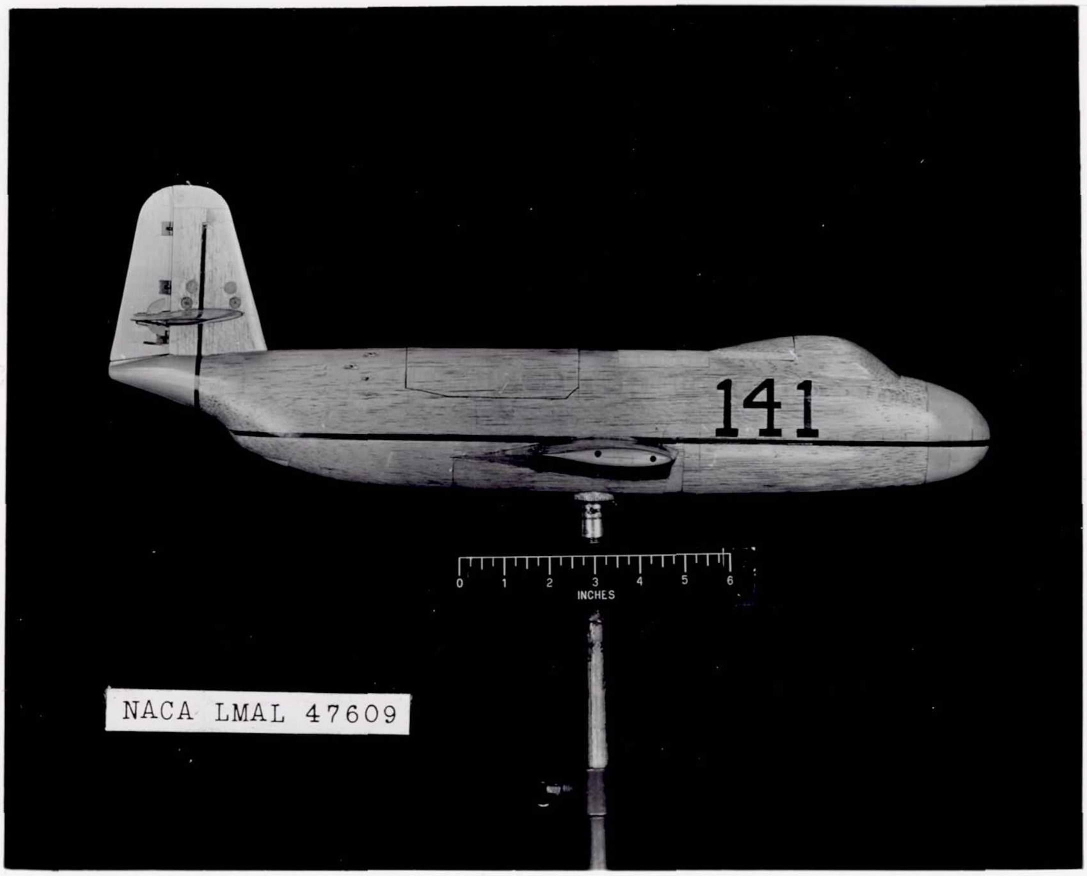


Figure 2.- Photograph of the $\frac{1}{20}$-scale model of the Chance-Vought XF6U-1 airplane in the high-speed condition (flaps and landing gear retracted).

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY – LANGLEY FIELD, VA.

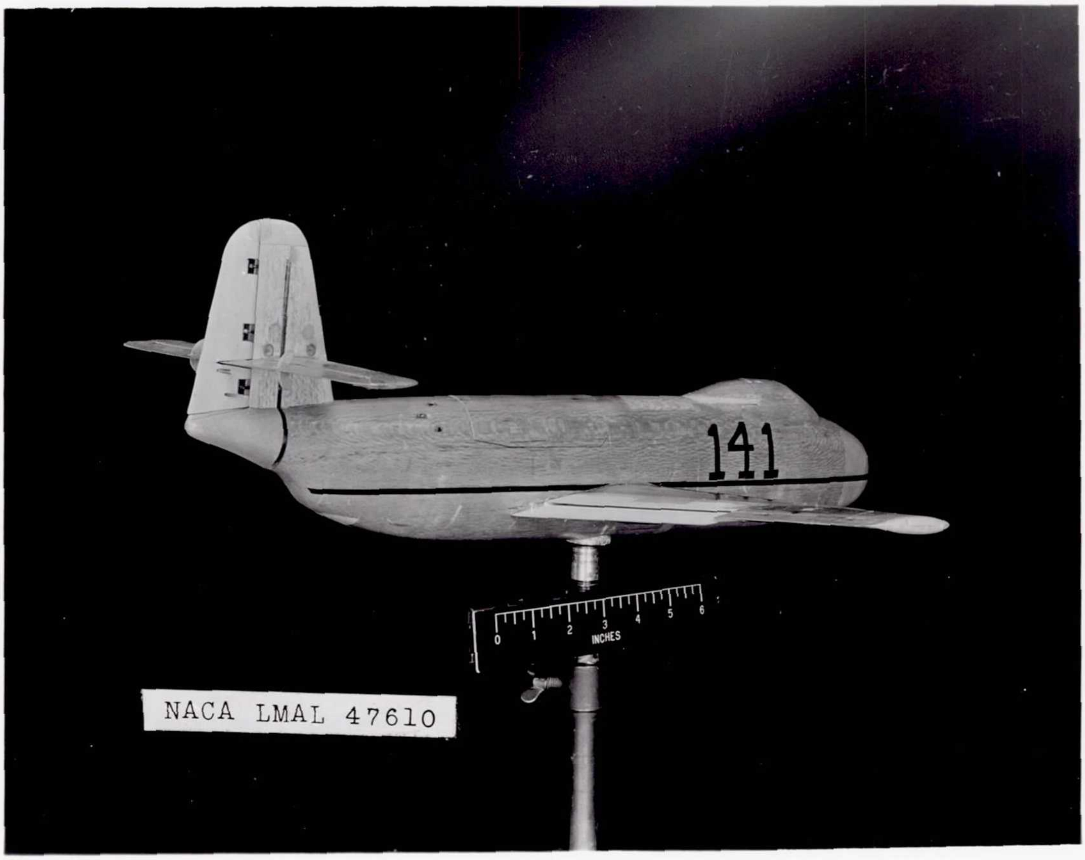


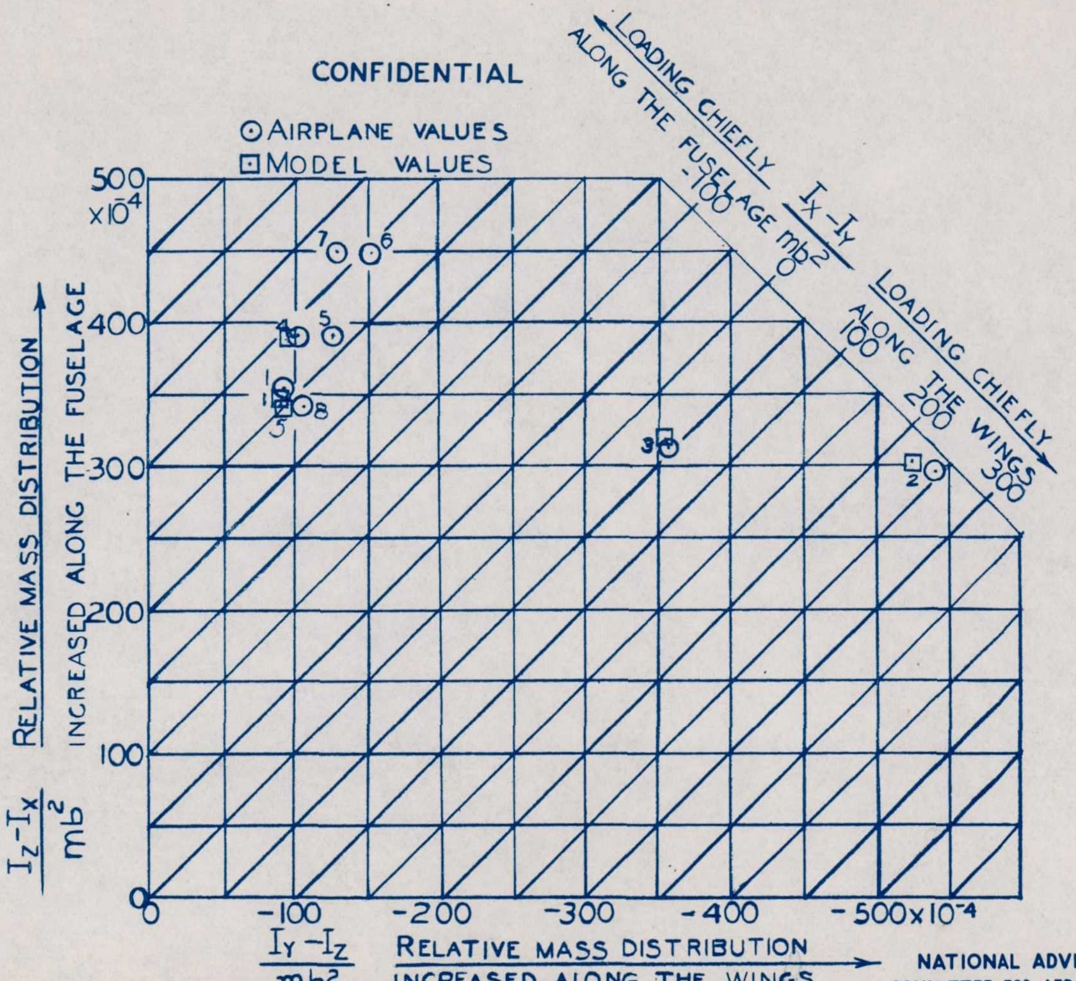
Figure 3.- Photograph of the $\frac{1}{20}$-scale model of the Chance-Vought XF6U-1 airplane in the cruising condition (flaps extended 4 degrees and landing gear retracted).

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA.

Figure 4.- Photograph of a $\frac{1}{20}$-scale model of the Chance-Vought XF6U-1 airplane with the wing-tip fuel tanks installed.

Figure 5.- Photograph showing the $\frac{1}{20}$-scale model of the Chance-Vought XF6U-1 airplane spinning in the 20-foot free-spinning tunnel.

CONFIDENTIAL



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

FIGURE 6.- MASS PARAMETERS FOR LOADINGS POSSIBLE ON THE XF6U-1 AIRPLANE AND FOR LOADINGS TESTED ON THE MODEL. (POINTS ARE FOR LOADINGS LISTED IN TABLE III.)

CONFIDENTIAL

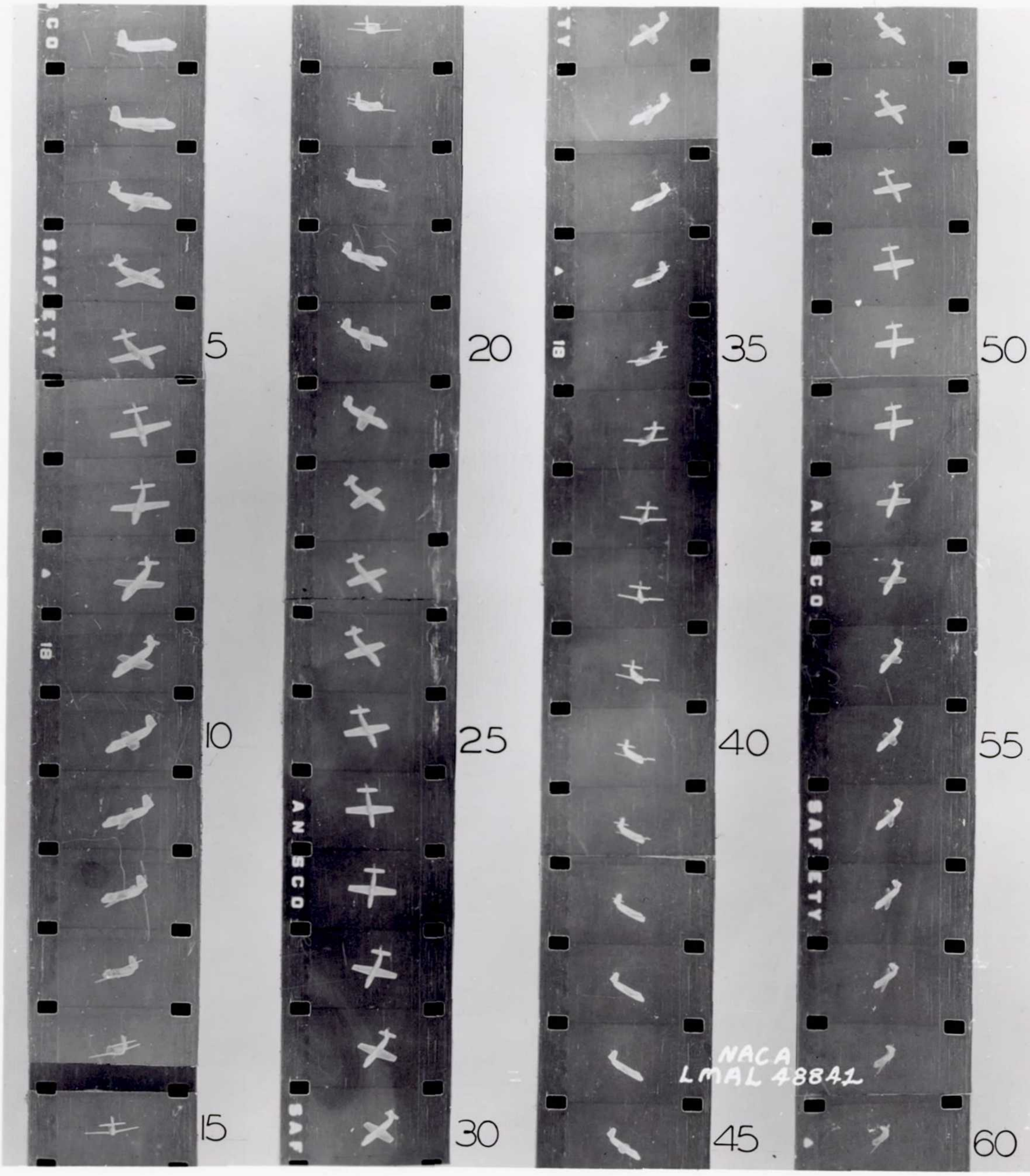


Figure 7.- Typical motion of a $\frac{1}{20}$-scale model of the XF6U-1 airplane with ailerons neutral, elevator full up, and rudder full with the spin. Normal fighter loading. 32 frames per second.

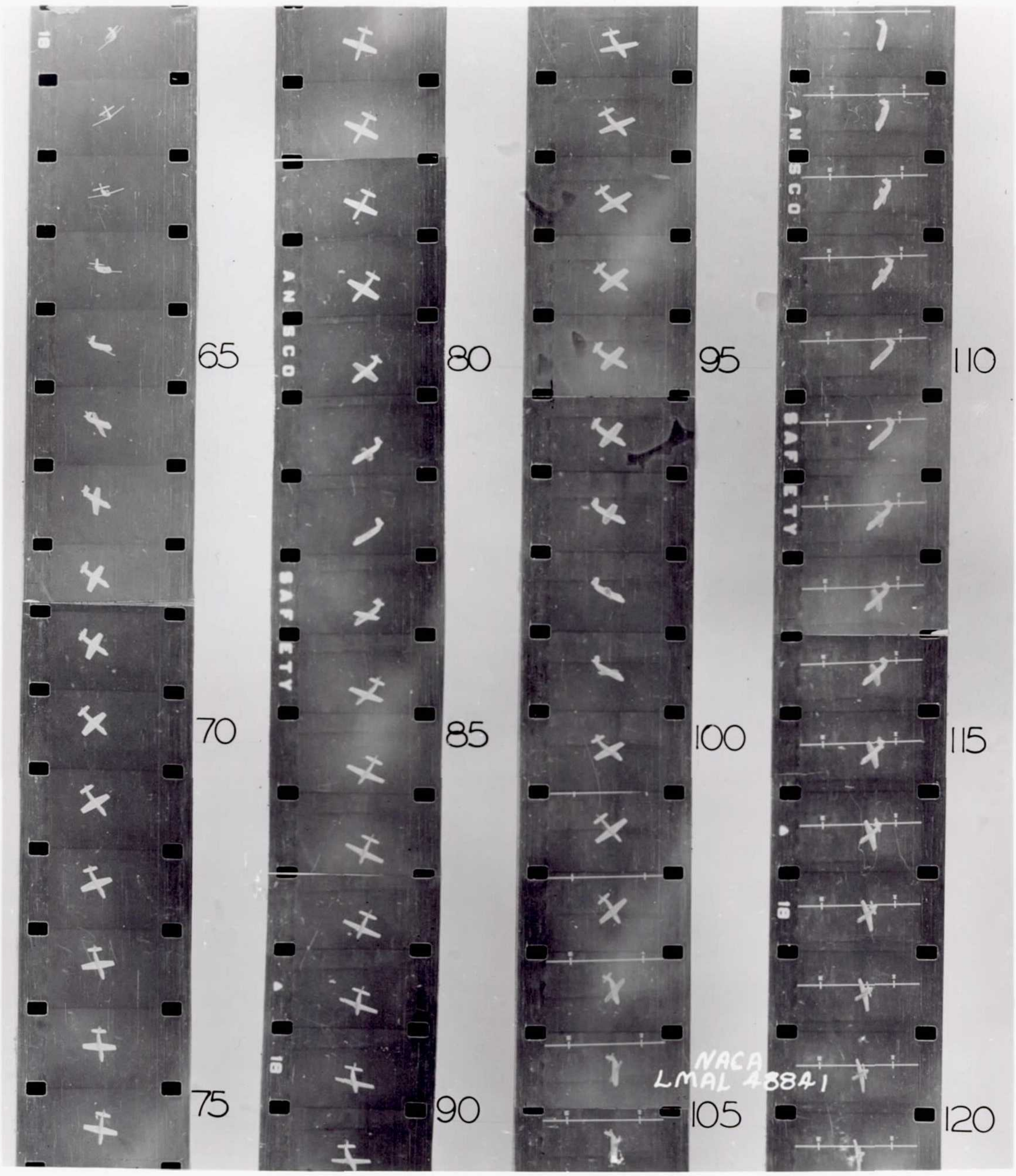


Figure 7.- Continued.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA.

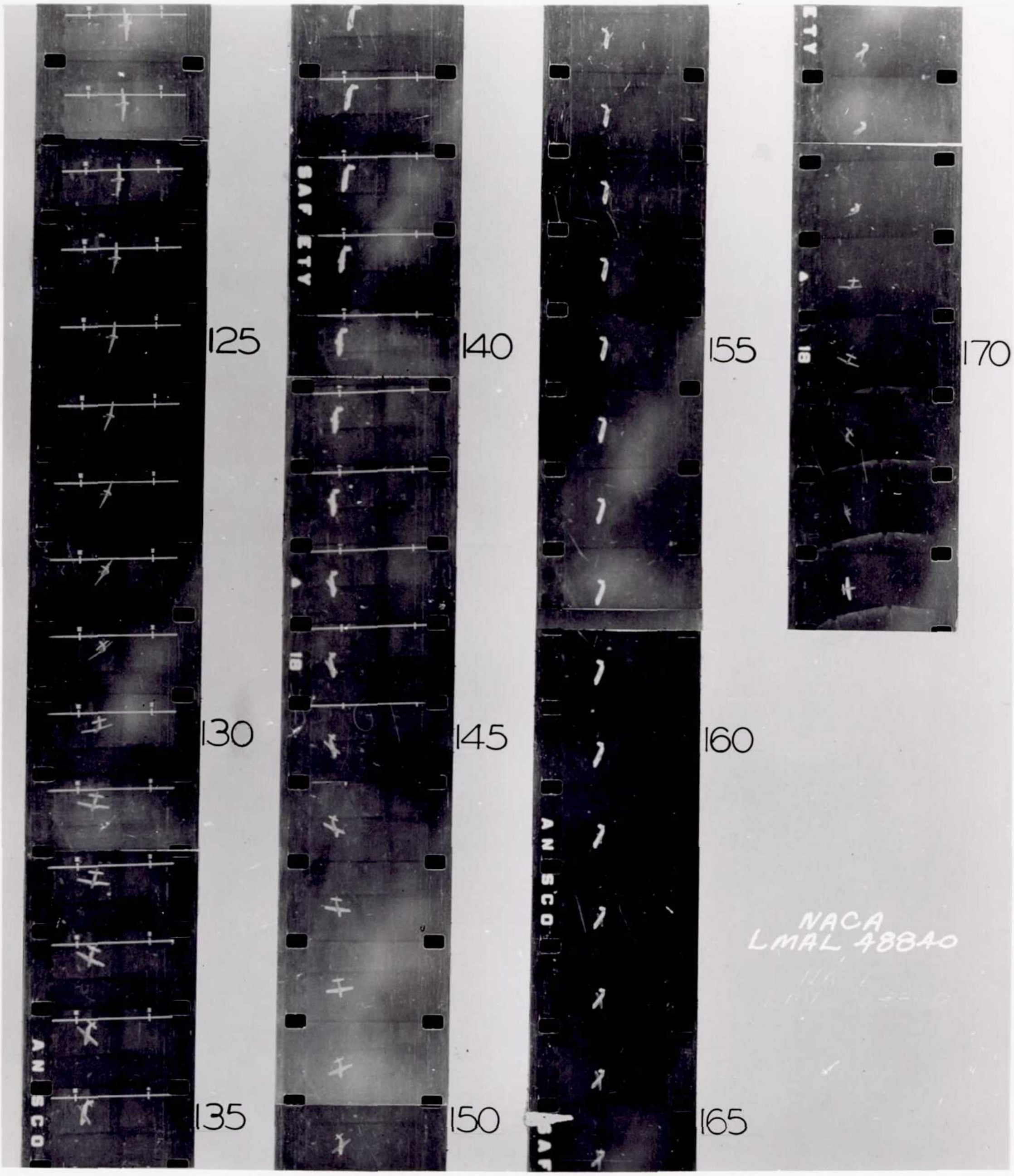


Figure 7.- Concluded.

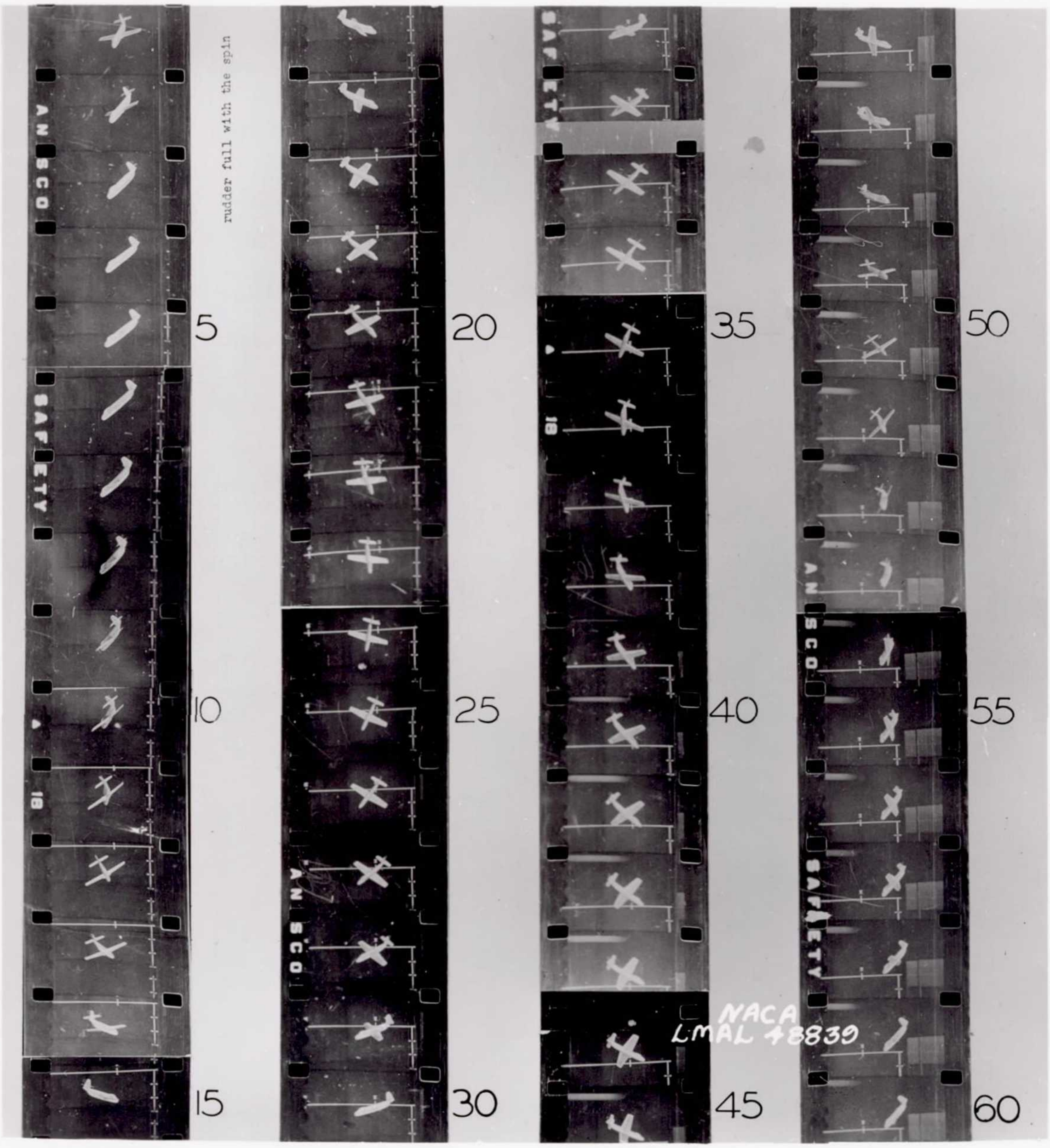


Figure 8.- Typical motion of a $\frac{1}{20}$-scale model of the XF6U-1 airplane during a recovery with the ailerons neutral and the elevator full up. Normal fighter loading. 32 frames per second.

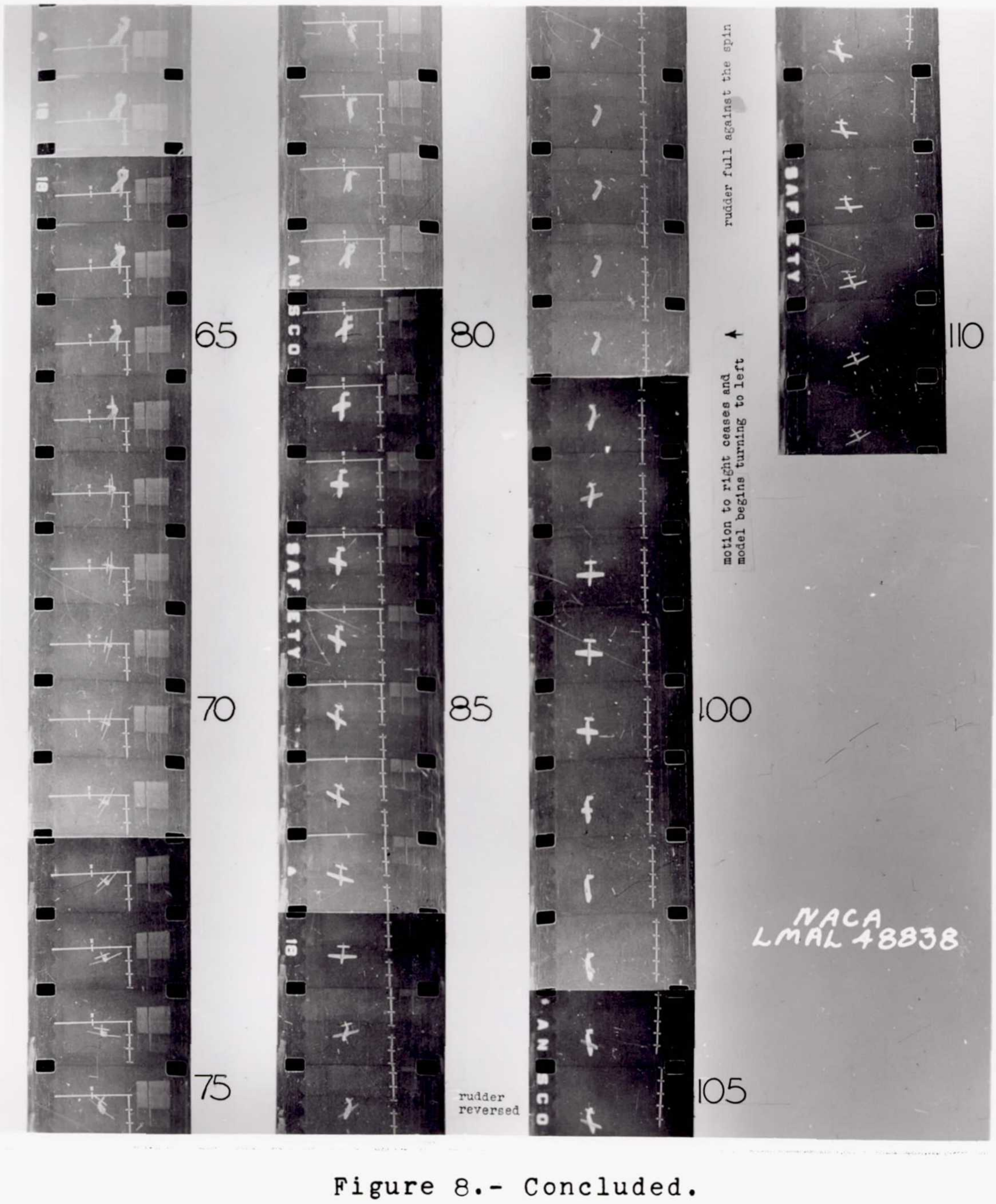


Figure 8.- Concluded.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA.

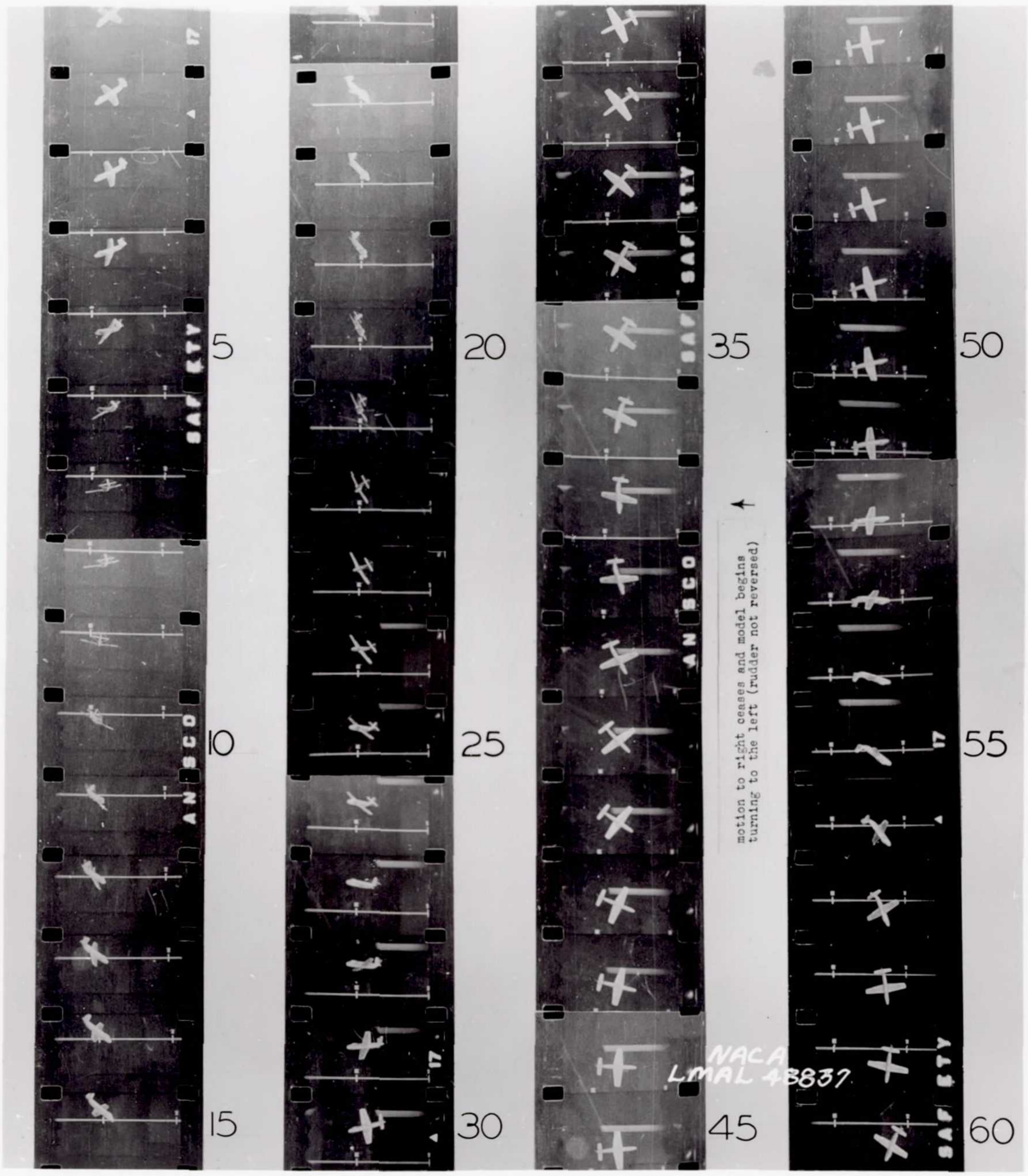


Figure 9.- Typical motion of a $\frac{1}{20}$-scale model of the XF6U-1 airplane with ailerons full against the spin, elevator full up, and rudder full with the spin. Normal fighter loading. 64 frames per second.

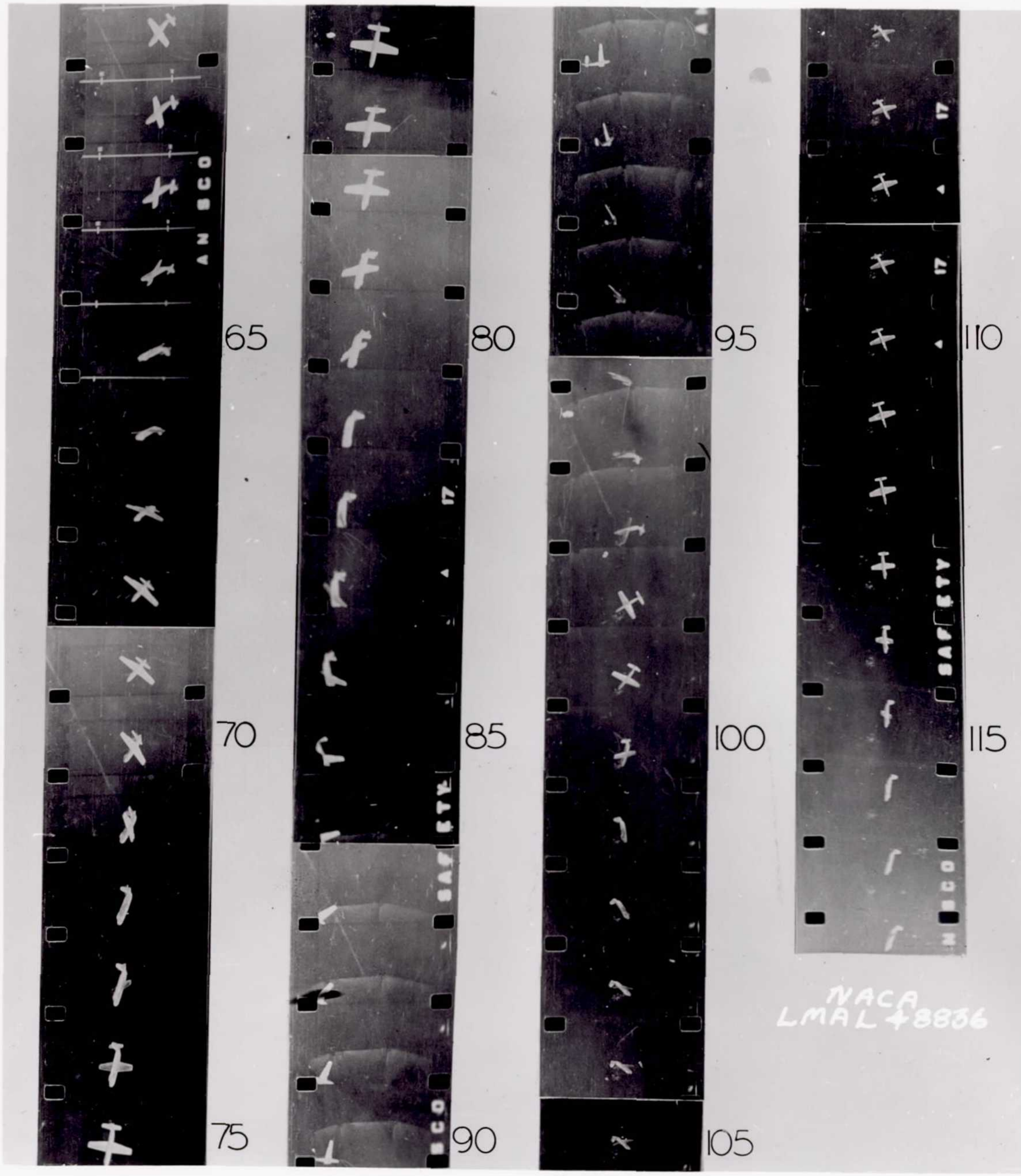


Figure 9.- Concluded.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA.

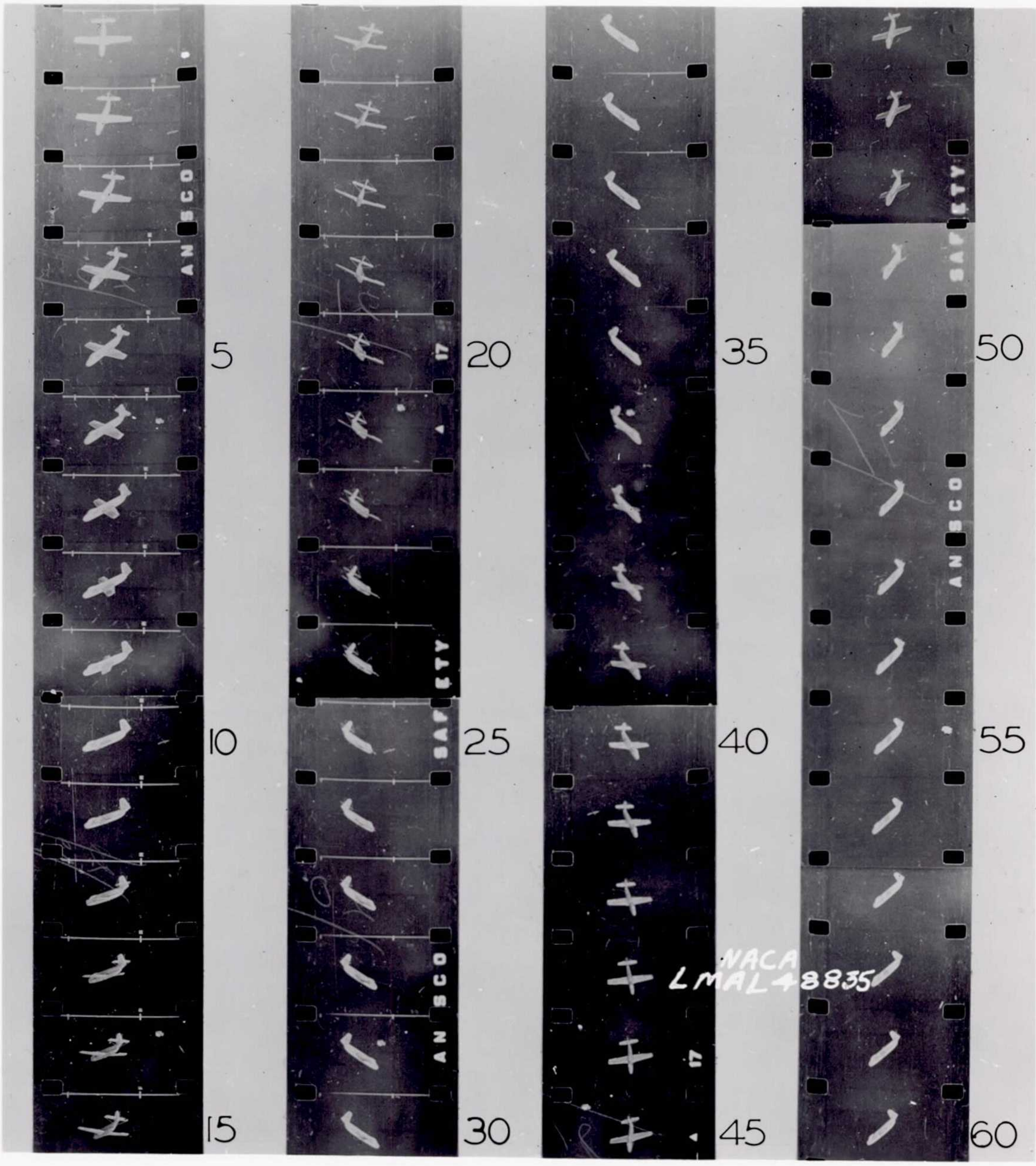


Figure 10.- Typical motion of a $\frac{1}{20}$-scale model of the XF6U-1 airplane with ailerons full with the spin, elevator full up, and rudder full with the spin. Normal fighter loading. 64 frames per second.

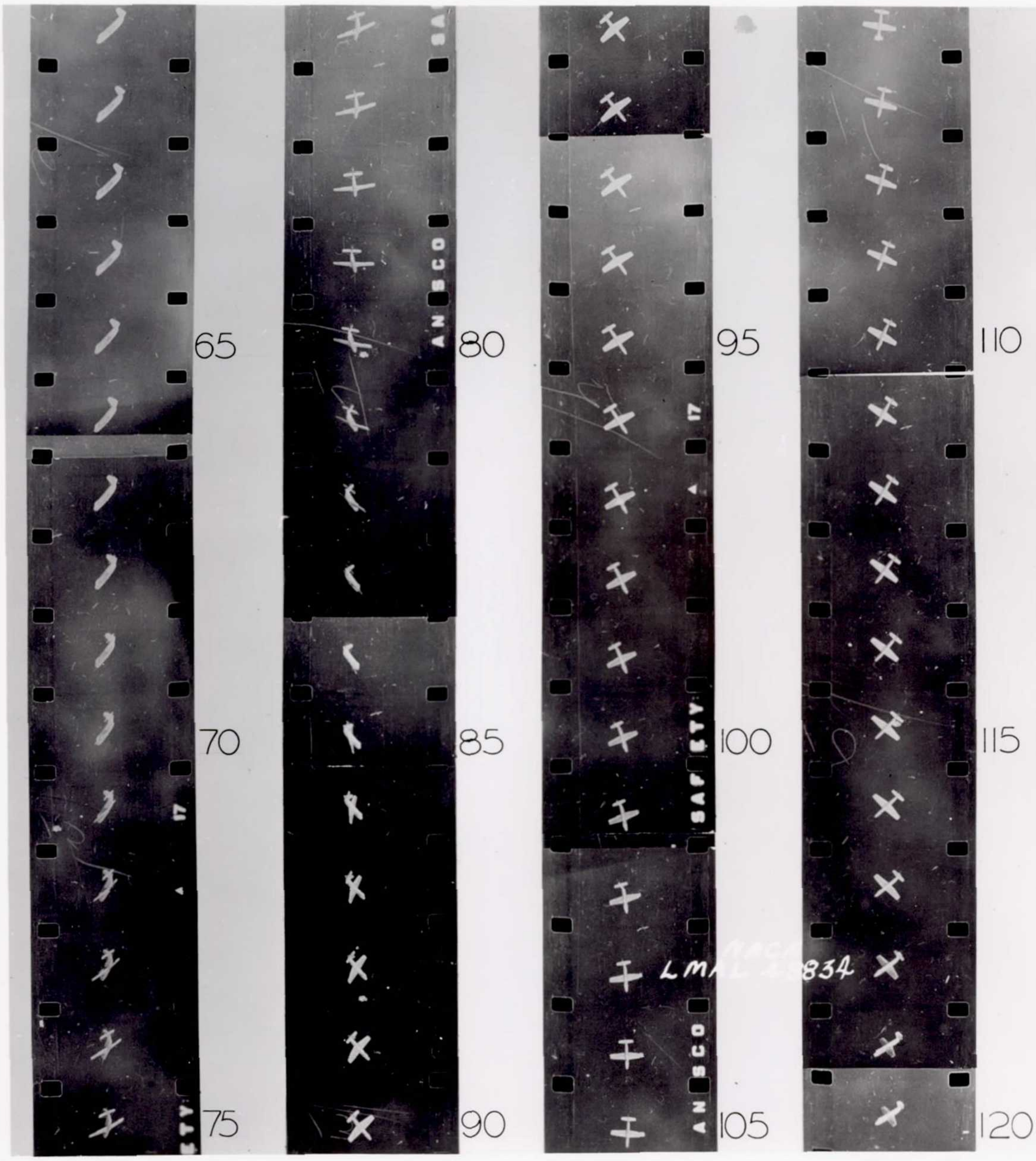


Figure 10.- Continued.

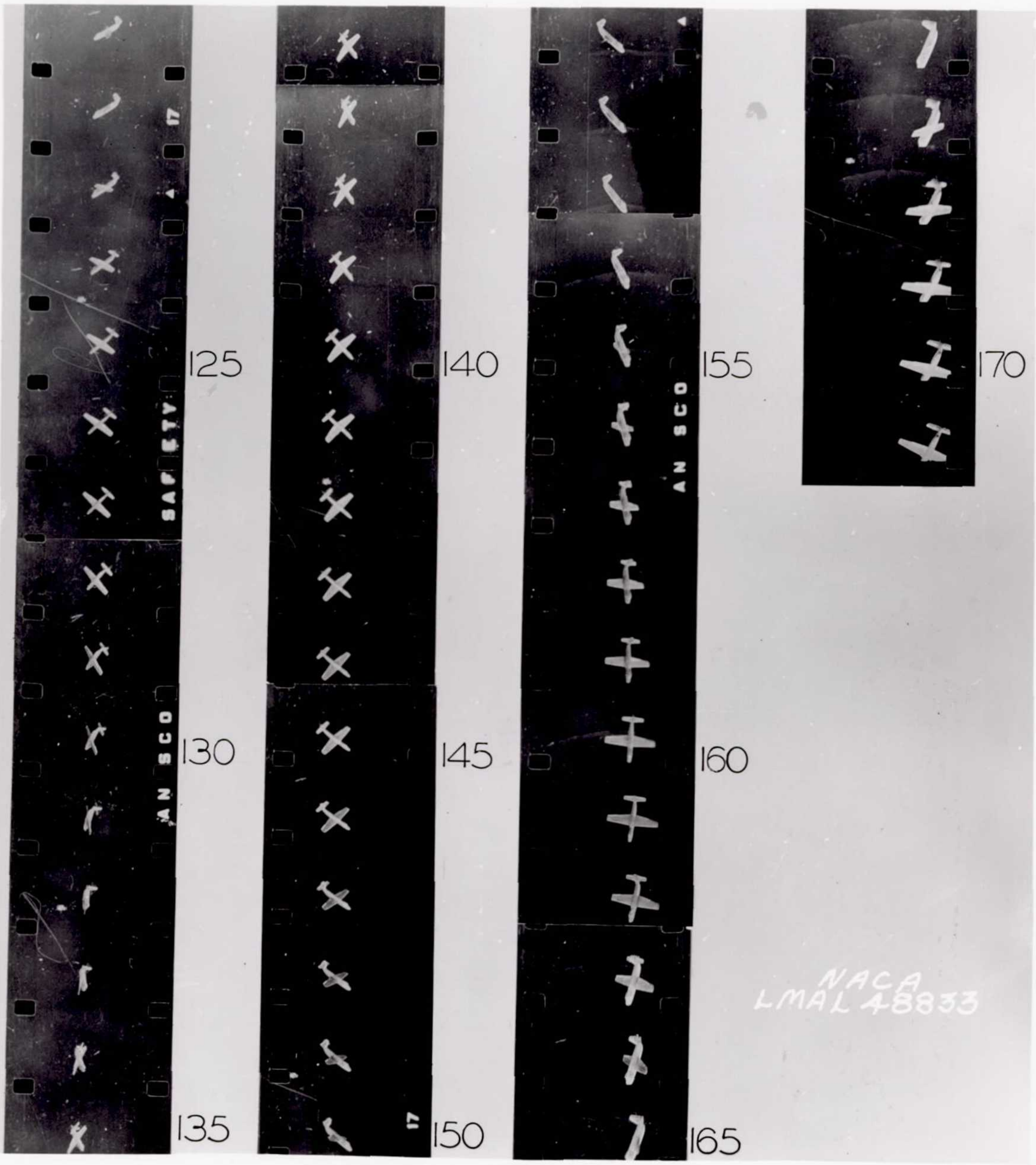


Figure 10.- Concluded.

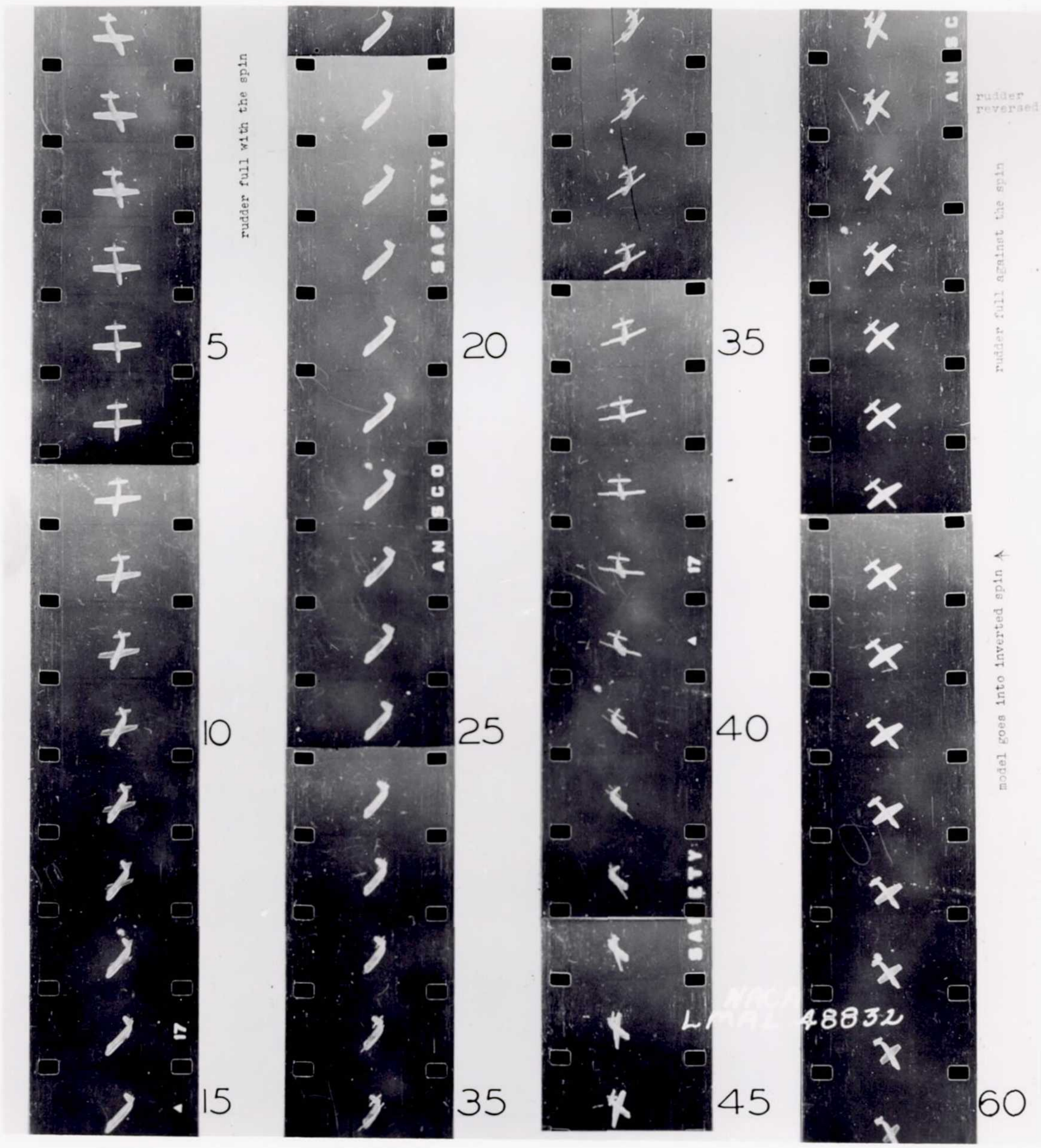


Figure 11.- Typical motion of a $\frac{1}{20}$-scale model of the XF6U-1 airplane during a recovery with the ailerons full with the spin and the elevator full up. Normal fighter loading. 64 frames per second.

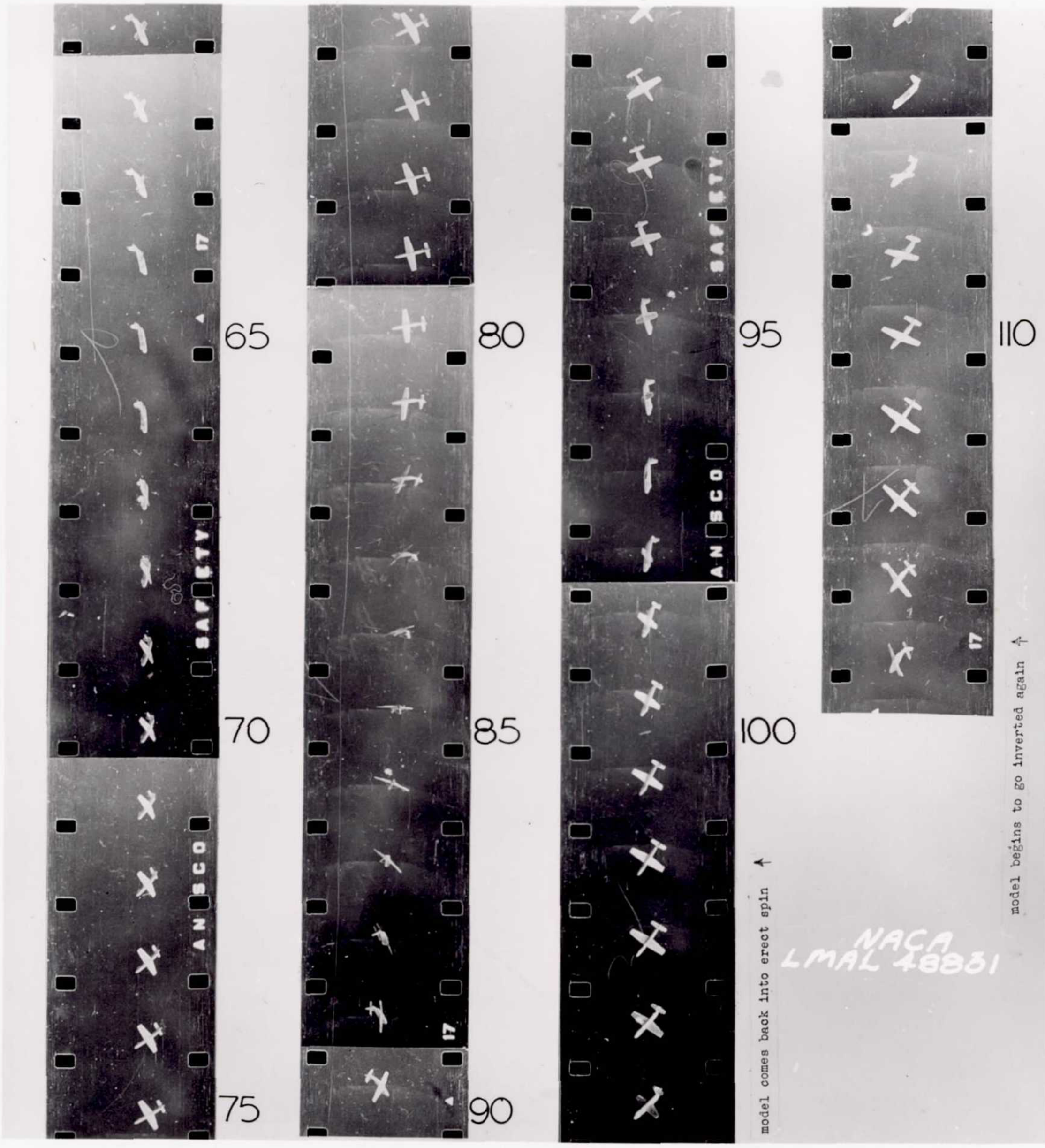


Figure 11.- Concluded.